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Evaluation of Tomato Cultivars for Processing

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INTRODUCTION

In Ohio tomatoes continue to be the most important processed crop, with planted acreage of 22,000 acres and one-half million ton production. Ohio ranks second only to California in processed tomato production (3).

The transition to new field production methods and new processing practices continues to create needs for a choice of more suitable cultivars. This research is directed toward improvement of the quality of the whole-pack product. The development of improved cultivars for use in manufacture of better quality of juice, sauce, and paste is also important (1, 2).

The objective of this study was to determine the suitability of 26 Ohio-grown tomato cultivars for processing quality canned products. The cultivars included were classified as established and/or new cultivars to Ohio tomato growers.

MATERIALS AND METHODS

The 1978 processing project included 26 tomato cultivars grown in replicated plots under acceptable commercial practices at the Ohio Agricultural Research and Development Center's Northwestern Branch near Hoytville. Each cultivar was machine harvested (with aid of FMC Western Model) with little or no sort on the harvester and bulk handled. Following harvest, the tomatoes were transported by truck (approximately 100 miles) to the Food Processing Pilot Plant at The Ohio State University, Columbus, for processing. All lots were processed after 24 hours hold following harvest as peeled whole tomatoes, juice, and 20% concentrate.

A. Twenty field-run tomatoes were randomly selected and used for objective and subjective raw quality evaluation.

1. The tomatoes were classified as Globe, Pear, Blocky, or Ovate in shape.
2. Size was determined by weighing a 20-tomato sample and then calculating the number per pound.
3. Objectively, stem scar length and stylar scar length were determined by measuring the average length in inches.
4. Firmness was determined subjectively and rated as soft, medium, and hard.
5. The sample was then quartered, extracted in a Berkel laboratory pulper, and deaerated.
   a. The deaerated pulp was presented to the Agtron E-5 instrument in a sample cup with the instrument calibrated at 48. The color reading was taken directly and recorded as such.
   b. The deaerated pulp was also presented to the Hunter Color Difference Meter D25 D3A in a standard plastic sample cup and the Hunter TMC value was taken directly and recorded as such.
   c. Percent soluble solids: An Abbe refractometer was used for direct determinations of percent soluble solids. The instrument was standardized with distilled water and all readings were converted to 70° C. (For the juice, the refractive index (RI) is also given.)
   d. pH: The pH was determined by the glass electrode method (Beckman Zeromatic pH meter) using 10 ml of tomato juice diluted with 90 ml of distilled water.
   e. Percent total acid as citric: The sample used for pH determination was directly titrated using 0.1 normal sodium hydroxide solution to a pH of 8.1. Calculations using the following equation were made:

$$\text{Percent acid} = \frac{(\text{No. of ml of 0.1 N NaOH})\,(.0064)}{10 \text{ ml sample}} \times 100$$

   f. Ascorbic acid: Ten ml aliquots of tomato juice were diluted with 90 ml of 1% metaphosphoric acid and filtered. A 10 ml aliquot of the filtrate was titrated with 0.2% 2, 6-dichlorophenolindophenol indicator solution. Milligrams of Vitamin C were determined by the following formula:

$$\text{Dye factor} \times \text{ml of dye} \times 100 = \frac{\text{mg vitamin C}}{100 \text{ g}}$$

   g. The sugar/acid ratio was calculated by dividing the percent soluble solids by the percent titratable acid.

B. Preparation and processing of the tomato: All tomatoes were prepared for canning by washing,

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lye peeling (18% caustic soda and Faspeel at 190° F (88° C) for 20 seconds), and processed in a still retort as whole tomatoes. Each lot of whole tomatoes was filled to 10.0-10.5 oz in No. 303 x 406 size fruit enamel tin cans with a 50-grain salt tablet containing 44.5% NaCl, 15% $CaSO_4 \cdot H_2O$, 37% citric acid, and 3.5% sodium bicarbonate.

C. Juice was made from each cultivar of tomato by washing, chopping, preheating to 190°-200° F (88°-93° C), extracted using an .023 inch screen in a Langsenkamp extractor, high temperature-short time sterilized (252° F [122° C], 42 sec), cooled to 200° F (93° C), filled in 303 x 406 enamel cans, 30-grain NaCl salt tablet added, closed, inverted and held for 3 minutes, and spin-cooled to 100° F (38° C) prior to casing and storage.

D. Grades of canned tomatoes: Grades were determined in accordance with the U. S. Standards for Grades of Canned Tomatoes.

RESULTS AND DISCUSSION

The data in Table 1 indicate 17 of the cultivars were Grade A quality for canned tomatoes. Of the new cultivars, Ohio 07663, 07814, 07723, 07724, 07731, and 07781 were the most outstanding. For juice, both regular and reconstituted from 20% concentrate, all were of high quality with Ohio cultivars 07630, 07721, 07678, 07759, and 076122 rated the highest. Some of these new cultivars, if meeting field production requirements, should be produced for processing as the canned products are equal to or better than products canned from conventional cultivars.

REFERENCES

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TABLE 1.—Tomato Cultivar Evaluation, Raw Product and Canned Whole Pack, 1978.

Lot No.	1	2	3	4
Cultivar Code	**Chico III**	**Campbell 37**	**H2867 (Heinz)**	**Castlex 1501**
Raw ($\bar{X}$/20 tom.)				
Fruit Shape	Globe	Blocky	Pear	Ovate
No./lb	5	6-7	7	6-7
Stem Scar	Over ½ inch	¼ - ½ inch	Less ¼ inch	¼ - ½ inch
Stylar Scar	Over ⅜ inch	None	None	⅜ inch
Firmness	Medium	Hard	Hard	Hard
E-5 Pulp Color	23	26.5	26	31.5
TMC Color	81.9	77	77.9	77.3
pH	4.44	4.46	4.50	4.44
T.A.	0.44	0.44	0.44	0.42
S.S.	5.6	5.8	6.8	6.6
Vitamin C	13.6	14.5	13.9	15.0
Canned ($\bar{X}$/3 cans)				
Drained Wt	16	16.3	18.3	18.3
Wholeness	19.7	19	20	19.7
Color	26.3*	29	29	26*
Defects	25.7	30	30	29
Total Score	87.7	94.3	97.3	93
Grade	B	A	A	B

Evaluation of Canned and Reconstituted Tomato Juice Samples, 1978	Chico III	Campbell 37	H2867 (Heinz)	Castlex 1501
Canned Juice				
pH	4.40	4.44	4.40	4.42
T.A.	0.41	0.43	0.47	0.44
R.I.	1.3425	1.3425	1.3430	1.3415
S.S.	6.4	6.6	7.0	6.0
Sugar/Acid	15.5	15.5	14.8	13.9
E-5	31	29	30	31.5
TMC	72.2	72.1	71.7	70.4
Vitamin C	10.4	12.0	14.8	9.5
Concentrate to 20% ± 0.4				
pH	4.38	4.46	4.38	
T.A.	1.50	1.50	1.72	
Reconstituted Juice				
pH	4.42	4.50	4.44	
T.A.	0.61	0.51	0.60	
R.I.	1.3425	1.3425	1.3430	
S.S.	6.4	6.6	7.0	
Sugar/acid	10.5	12.9	11.7	
E-5	29	27	29	
TMC	71.5	73	72.2	
Vitamin C	15.9	17.0	14.0	

*Limiting rule

TABLE 1 (Continued).—Tomato Cultivar Evaluation, Raw Product and Canned Whole Pack, 1978.

Lot No.	5	6	7	8	9	10
Cultivar Code	**Sea 77**	**07630**	**07663**	**07667**	**07681**	**07814**
Raw ($\bar{X}$/20 tom.)						
Fruit Shape	Ovate	Pear	Ovate	Globe	Globe	Ovate
No./lb	4-5	6	8	6	3-4	8
Stem Scar	Over ½ inch	Less ¼ inch	¼ - ½ inch	¼ - ½ inch	Over ½ inch	¼ - ½ inch
Stylar Scar	None	None	⅜ inch	⅛ inch	Over ⅜ inch	⅛ inch
Firmness	Medium	Medium	Medium	Hard	Hard	Hard
E-5 Pulp Color	22	24	25	27	20	26
TMC Color	80.1	81.8	78.3	78.0	84.4	79.2
pH	4.58	4.50	4.64	4.55	4.60	4.32
T.A.	0.27	0.30	0.37	0.33	0.25	0.48
S.S.	5.0	5.2	5.7	6.0	5.6	5.2
Vitamin C	16.2	14.8	16.5	13.4	19.2	15.6
Canned ($\bar{X}$/3 cans)						
Drained Wt	18.7	17	20	17	16.3	18
Wholeness	20	19.3	19.3	18.3	19.3	20
Color	29.3	28.3	28	28	27	29
Defects	27	30	30	30	24*	30
Total Score	95	94.6	97.3	93.3	86.6	97
Grade	A	A	A	A	B	A
Comments	veiny				†	

Evaluation of Canned and Reconstituted Tomato Juice Samples, 1978

	Sea 77	07630	07663	07667	07681	07814
Canned Juice						
pH	4.52	4.48	4.46	4.44	4.54	4.42
T.A.	0.34	0.39	0.42	0.46	0.32	0.44
R.I.	1.3420	1.3420	1.3430	1.3430	1.3425	1.3420
S.S.	6.2	6.2	6.8	6.8	6.5	6.0
Sugar/acid	18.8	16.1	15.6	14.6	20.4	13.6
E-5	31	32	30.5	30	29	31
TMC	72	71.5	70.7	71.7	75.3	71.7
Vitamin C	11.6	11.6	13.5	9.2	13.2	10.7
Concentrate to 20% ± 0.4						
pH	4.50	4.48	4.46	4.44	4.54	
T.A.	1.10	1.10	1.33	1.33	1.01	
Reconstituted Juice						
pH	4.56	4.54	4.52	4.50	4.62	
T.A.	0.35	0.38	0.44	0.49	0.36	
R.I.	1.3420	1.3420	1.3430	1.3430	1.3425	
S.S.	6.2	6.2	6.8	6.8	6.5	
Sugar/acid	17.7	16.3	15.5	13.9	18.0	
E-5	30	31	28	28	27	
TMC	70	71.1	72	73	74.2	
Vitamin C	15.9	14.1	17.7	14.7	16.5	

*Limiting rule
†Noticeable stem scar

TABLE 1 (Continued).—Tomato Cultivar Evaluation, Raw Product and Canned Whole Pack, 1978.

Lot No.	11	12	13	14	15	16
Cultivar Code	**07721**	**07723**	**07724**	**07668**	**07678**	**07731**
Raw ($\bar{X}$/20 tom.)						
Fruit Shape	Ovate	Blocky	Ovate	Ovate	Ovate	Ovate
No./lb	7	7	5	10	9	1
Stem Scar	¼ - ½ inch	¼ - ½ inch	¼ - ½ inch	¼ - ½ inch	¼ - ½ inch	¼ - ½ inch
Stylar Scar	⅛ inch	None	None	None	None	None
Firmness	Hard	Hard	Hard	Hard	Hard	Hard
E-5 Pulp Color	28	27	22	28.5	20	22
TMC Color	76.7	78.7	83.7	85.7	82.8	84.2
pH	4.50	4.50	4.60	4.46	4.42	4.50
T.A.	0.37	0.37	0.27	0.31	0.47	0.34
S.S.	5.8	5.7	5.2	5.2	5.5	4.8
Vitamin C	14.5	13.3	18.6	18.6	19.7	18.0
Canned ($\bar{X}$/3 cans)						
Drained Wt	17	18.7	18.3	17	20	18
Wholeness	18	19.7	20	20	20	20
Color	28	28	29	27	23*	30
Defects	30	30	30	30	30	30
Total Score	93	96.4	97.3	94	93	98
Grade	A	A	A	A	C	A

Evaluation of Canned and Reconstituted Tomato Juice Samples, 1978

	07721	07723	07724	07668	07678	07731
Canned Juice						
pH	4.48	4.48	4.58		4.46	4.55
T.A.	0.38	0.40	0.34		0.39	0.33
R.I.	1.3420	1.3420	1.3425		1.3420	1.3420
S.S.	6.0	6.0	6.4		6.2	6.2
Sugar/acid	15.8	15.3	18.7		15.9	18.6
E-5	32	32	28		38	27
TMC	71.1	72.2	75.5		69.5	76.2
Vitamin C	11.6	10.7	16.8		12.9	16.5
Concentrate to 20% ± 0.4						
pH	4.46	4.40	4.48			4.44
T.A.	1.40	1.43	1.25			1.17
Reconstituted Juice						
pH	4.54	4.52	4.62			4.56
T.A.	0.43	0.42	0.42			0.42
R.I.	1.3420	1.3420	1.3425			1.3420
S.S.	6.0	6.0	6.4			6.2
Sugar/acid	14.0	14.3	15.2			14.8
E-5	29	30	27			25
TMC	72.3	70.7	74			76.1
Vitamin C	15.3	14.4	18.0			21.0

*Limiting rule

TABLE 1 (Continued).—Tomato Cultivar Evaluation, Raw Product and Canned Whole Pack, 1978.

Lot No.	17	18	19	20	21	22
Cultivar Code	**07759**	**076122**	**07770**	**077143**	**07872**	**07781**
Raw ($\bar{X}$/20 tom.)						
Fruit Shape	Blocky	Ovate	Pear	Ovate	Globe	Ovate
No./lb	6-7	7-8	5-6	11-12	4-5	10
Stem Scar	¼ - ½ inch	¼ - ½ inch	¼ - ½ inch	Less ¼ inch	¼ - ½ inch	¼ - ½ inch
Stylar Scar	None	None	None	None	⅛ inch	⅛ inch
Firmness	Hard	Hard	Hard	Hard	Medium	Hard
E-5 Pulp Color	25	26	23	20.5	27	26
TMC Color	81.4	80.1	82.2	82.9	78.8	81.2
pH	4.60	4.52	4.60	4.60	4.42	4.42
T.A.	0.32	0.33	0.27	0.29	0.36	0.37
S.S.	5.4	5.2	5.2	5.6	5.2	5.4
Vitamin C	17.7	14.5	16.8	18.6	14.2	17.4
Canned ($\bar{X}$/3 cans)						
Drained Wt	17.7	16.7	17.3	7.3	16.7	18
Wholeness	18.3	20	18.3	18.7	19.3	20
Color	28	28	26*	27	25.7*	30
Defects	30	30	29	29	27	30
Total Score	94	94.7	90.6	92	88.7	98
Grade	A	A	B	A	B	A
Comments						

Evaluation of Canned and Reconstituted Tomato Juice Samples, 1978

	07759	076122	07770	077143	07872	07781
Canned Juice						
pH	4.52	4.44	4.46		4.40	
T.A.	0.41	0.39	0.36		0.43	
R.I.	1.3430	1.3425	1.3425		1.3425	
S.S.	6.8	6.5	6.4		6.5	
Sugar/acid	16.6	16.5	17.7		15.3	
E-5	32	29	31.5		34	
TMC	71.2	74	72.2		69.6	
Vitamin C	11.9	12.9	15.9		10.8	
Concentrate to 20% ± 0.4						
pH	4.42	4.36	4.50		4.34	
T.A.	1.37	1.42	1.15		1.40	
Reconstituted Juice						
pH	4.54	4.50	4.62		4.48	
T.A.	0.49	0.44	0.38		0.49	
R.I.	1.3430	1.3425	1.3425		1.3425	
S.S.	6.8	6.5	6.4		6.5	
Sugar/acid	13.9	14.8	16.8		13.3	
E-5	28	26	28		32	
TMC	71.4	74.7	72.5		69.2	
Vitamin C	16.2	16.2	8.6		15.6	

*Limiting rule

TABLE 1 (Continued).—Tomato Cultivar Evaluation, Raw Product and Canned Whole Pack, 1978.

Lot No.	23	24	25	26
Cultivar Code	**07891**	**Kagome 70**	**Kagome 77**	**Wase Daruma**
Raw ($\bar{X}$/20 tom.)				
Fruit Shape	Ovate	Oblate	Globe	Globe
No./lb	7	5-6	5-6	6-7
Stem Scar	¼ - ½ inch	Over ½ inch	¼ - ½ inch	¼ - ½ inch
Stylar Scar	¼ inch	Over ⅜ inch	Over ⅜ inch	¼ inch
Firmness	Hard	Medium	Hard	Medium
E-5 Pulp Color	25	23	23	28.5
TMC Color	83.6	81.4	79.8	75.1
pH	4.45	4.50	4.45	4.36
T.A.	0.37	0.37	0.40	0.41
S.S.	5.2	5.8	5.6	5.2
Vitamin C	14.8	19.5	17.1	25.2
Canned ($\bar{X}$/3 cans)				
Drained Wt	18	16	18	16
Wholeness	20	20	18 7	18
Color	26.3*	23.7*	28	24*
Defects	27	27	30	27
Total Score	91.3	86.7	94.7	85
Grade	B	C	A	B
Comments	veiny		stem scar	green stem scar
Evaluation of Canned and Reconstituted Tomato Juice Samples, 1978				
	07891	**Kagome 70**	**Kagome 77**	**Wase Daruma**
Canned Juice				
pH	4.45	4.38	4.40	
T.A.	0.39	0.42	0.42	
R.I.	1.3425	1.3425	1.3420	
S.S.	6.4	6.6	6.5	
Sugar/acid	16.7	14.9	15.5	
E-5	34	29	29	
TMC	70	73.1	73.4	
Vitamin C	12.9	16.2	20.7	
Concentrate to 20% ± 0.4				
pH	4.42	4.28	4.26	
T.A.	1.27	1.41	1.46	
Reconstituted Juice				
pH	4.52	4.40	4.42	
T.A.	0.43	0.52	0.51	
R.I.	1.3425	1.3425	1.3420	
S.S.	6.4	6.6	6.5	
Sugar/acid	14.9	12.7	12.75	
E-5	30	29	28	
TMC	71.4	72.4	73.6	
Vitamin C	15.6	20.4	22.2	

*Limiting rule

Prediction of Finished Product Juice Color from Raw Product Tomato Color

DENNIS INKROTT and W. A. GOULD[1]

INTRODUCTION

Color is a very important aspect of the quality of tomatoes. Further, the tomato industry considers it one of the major criteria for grading tomatoes for processing (1). Color is one of the attributes of quality for all products canned from tomatoes. There is a relationship between raw and finished product tomato color, but prediction of the finished product color from the raw tomato color is difficult. Factors which influence raw tomato color and which could influence processed tomato color include variety or cultivar, climatic conditions, maturity of the tomato at harvest, and/or holding prior to processing.

This study had an overall objective to develop a procedure which would accurately correlate raw and processed tomato color.

The specific objectives were:

- To establish a standard curve for color values of raw vs. cooked tomato juice.
- To establish the effect of cooking time to predict the color of tomato juice.
- To compare various objective methods of color determination; *i.e.*, Hunter a/b, Tomato Color Index, and Agtron E-5.

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MATERIALS AND METHODS

Two varieties (cultivars) of tomatoes were used. They will be referred to as variety "A" (New Yorker), obtained from the OSU horticulture farm in Columbus, Ohio, and variety "B" (C-37), obtained from a commercial field in northwest Ohio.

Mature red and green fruit were weighed and mixed proportionally to give 100%, 95%, 90%, 85%, and 80% ripe for each variety. Each of the proportions was extracted through a U. S. Berkel extractor (screen size .033 in.) and deaerated using a vacuum pump. Each proportion was volumetrically divided into nine 250 ml samples which were transferred to 303 tin-plate containers. The samples were subjected to the following treatments:

1) No heating, raw sample
2) Heat to boil*, cool in ice bath
3) Heat to boil, transfer to 200° F oil bath for 2 minutes, cool

*The samples were heated to boil using an oil bath set at 380° F with a constant stirring during heating. Lids were placed on these containers immediately after boiling prior to transfer to the 200° F oil bath to prevent evaporation of the juice. Any foam present on the top of the juice after heating was skimmed off prior to cooling. The samples were cooled to 75° F and colorimetrically evaluated on the Hunter Color and Color Difference Meter D25 standardized on Hunter tile D33C-1585 (L = 25.60, a = 27.70, b = 12.10 and TCI = 71.58) and the Agtron E-5 standardized at 48 on the scale of 0-100.

TABLE 1.—Color Data for Variety "A" at Various Times of Cooking by Maturity

		Time of Cook at 200° F after Boiling (min)							
Percent Ripe	Raw	0	2	5	10	15	30	60	90
Hunter a/b Values									
100	2.52	1.99	1.94	1.94	1.93	1.88	1.86	1.85	1.85
95	2.23	1.84	1.76	1.74	1.73	1.71	1.71	1.68	1.64
90	2.16	1.82	1.80	1.74	1.71	1.68	1.66	1.66	1.64
85	1.95	1.66	1.64	1.61	1.57	1.56	1.55	1.54	1.52
80	1.88	1.63	1.58	1.57	1.53	1.52	1.50	1.49	1.47
Agtron E-5 Values									
100	30	39.5	40	40	40	42	43	43	43
95	46	55	53	55	56	53	54	54	52
90	43	47	47	49	49.5	49.5	50.5	50.5	50.5
85	53.5	55	55	55	55	56	56	56	56
80	55	55	57	57	57.5	57.5	57.5	58	58
Tomato Color Index (TCI)									
100	71.77	66.51	66.44	65.61	65.19	65.40	65.27	64.97	64.78
95	69.18	61.35	61.06	60.80	60.58	60.37	60.50	60.11	60.55
90	69.87	61.79	60.98	61.01	61.53	61.28	61.28	60.11	60.55
85	66.76	60.35	59.60	59.76	59.55	59.16	59.22	59.27	59.26
80	67.04	58.19	58.43	57.92	57.82	57.74	57.48	57.21	57.76

TABLE 2.—Color Data for Variety "B" at Various Times of Cooking by Maturity

Percent Ripe	Raw	Time of Cook at 200° F after Boiling (min) 0	2	5	10	15	30	60	90
Hunter a/b Values									
100	2.43	2.08	2.03	2.03	2.03	2.00	2.00	1.99	1.97
95	2.30	1.97	1.94	1.91	1.90	1.85	1.88	1.89	1.89
90	2.15	1.92	1.89	1.88	1.85	1.84	1.82	1.81	1.77
85	2.02	1.82	1.81	1.79	1.77	1.76	1.72	1.72	1.70
80	1.87	1.71	1.68	1.66	1.67	1.64	1.65	1.61	1.61
Agtron E-5 Values									
100	25.5	33	33	33	33.5	33.5	33.5	34.5	34.5
95	28	35	35	35.5	36	36	36	36.5	37
90	35	37	37.5	38	38	38	38.5	39.5	39.5
85	40	41	41	41	41	41	41.5	43	43
80	46	46	46	46	46	46	46	46.5	46.5
Tomato Color Index (TCI)									
100	77.27	72.51	72.35	71.36	71.15	71.33	71.03	71.14	71.38
95	76.23	70.17	69.77	69.39	69.57	68.24	68.12	69.35	68.85
90	74.62	69.85	69.50	69.35	69.04	69.21	68.88	69.10	68.91
85	74.37	68.79	68.61	68.29	68.26	67.94	67.98	67.80	67.68
80	72.74	67.60	67.43	67.01	67.13	66.60	66.55	66.20	66.47

4) Heat to boil, transfer to 200° F oil bath for 5 minutes, cool
5) Heat to boil, transfer to 200° F oil bath for 10 minutes, cool
6) Heat to boil, transfer to 200° F oil bath for 15 minutes, cool
7) Heat to boil, transfer to 200° F oil bath for 30 minutes, cool
8) Heat to boil, transfer to 200° F oil bath for 60 minutes, cool
9) Heat to boil, transfer to 200° F oil bath for 90 minutes, cool

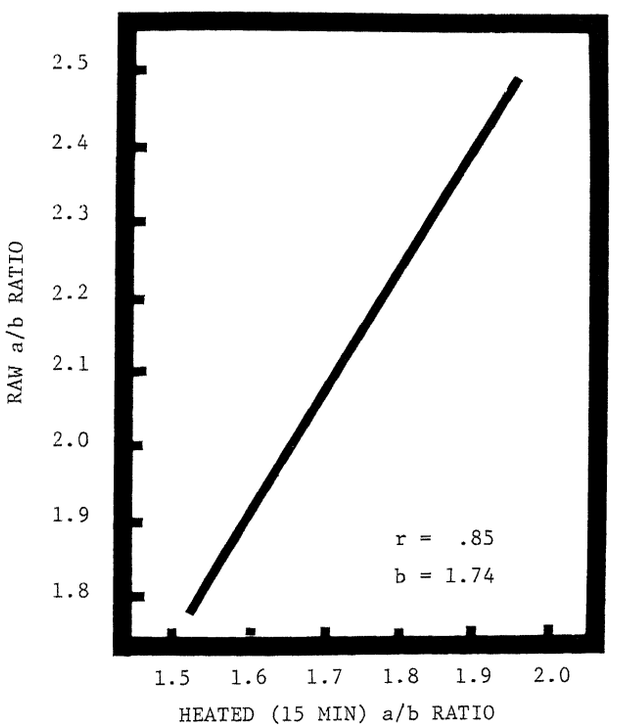

FIG. 1.—Correlation of raw vs. heated—a/b ratios.

RESULTS AND DISCUSSION

The data (Tables 1 and 2) show that a standard curve for color of raw vs. processed tomato juice can be developed. Various studies indicate that different cultivars differ in their lycopene pigment content and will vary in the amount of redness lost during heating (1). Most of the color loss in tomato juice occurs during the initial heating (3). Mohr (1976) attributes the loss of redness due to a decrease in lycopene present and an increase in yellow carotenoids in relation to the lycopene (2).

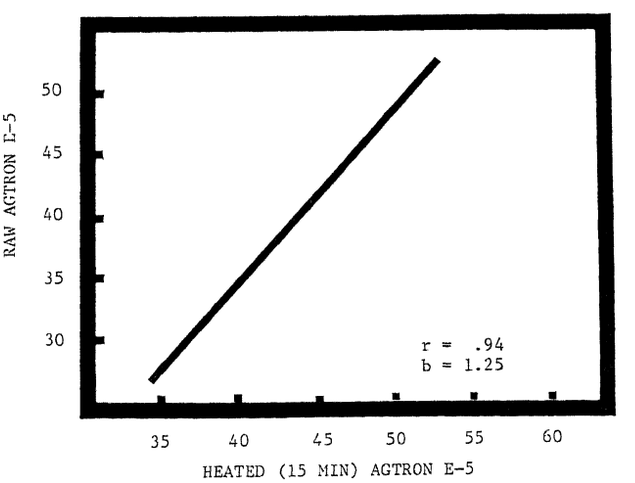

FIG. 2.—Correlation of raw vs. heated—Agtron E-5.

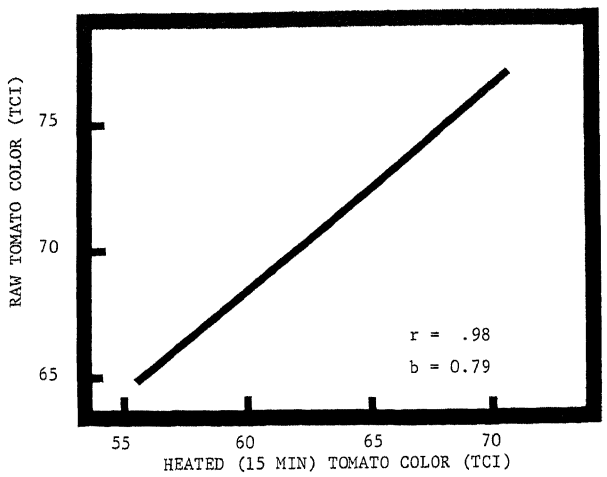

FIG. 3.—Correlation of raw vs. heated tomato color (TCI).

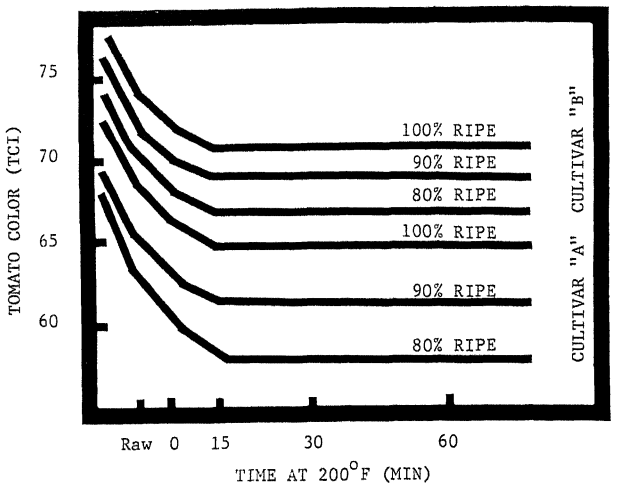

FIG. 4.—Effect of heating on tomato color.

After 15 minutes of heating (Figure 4) of the tomato juice at 200° F following the initial heating period, there is no great amount of change in color in the Hunter a/b, TCI, and the Agtron E-5. Because tomato color changed very little after this period, it is possible that the color readings obtained in this process are equivalent to those in the industrial process (Table 3). Standard curves were plotted (Figs. 1, 2, 3) and the curves show the relationship between raw juice and juice which was heated to boiling and then held for 15 minutes at 200° F. The data for each curve were developed by plotting the points which correspond to the percent of ripe tomatoes in the sample vs. heating time. The purpose of these curves is to give a wide range of color values so that predictions can be made of processed juice color based on the actual color of the raw sample.

The color data (Table 3) show that there is variation in the amount of redness lost during proces-

TABLE 3.—Comparison of Raw Tomato Color (Agtron E-5 and TCI) vs. Canned Juice Color by Cultivars.

	Agtron E-5		TCI Values	
Cultivar	Raw	Juice	Raw	Juice
Chico III	23	31	81.9	72.2
Campbell 37	26.5	29	77	72.1
H2867 (Heinz)	26	30	77.9	71.7
Castlex 1501	31.5	31.5	77.3	70.4
Sea 77	22	31	80.1	72
07630	24	32	81.8	71.5
07663	25	30.5	78.3	70.7
07667	27	30	78.0	71.7
07681	20	29	84.4	75.3
07814	26	31	79.2	71.7
07721	28	32	76.7	71.1
07723	27	32	78.7	72.2
07724	22	28	83.7	75.5
07678	20	38	82.8	69.5
07731	22	27	84.2	76.2
07759	25	32	81.4	71.2
076122	26	29	80.1	74
07770	23	31.5	82.2	72.2
07872	27	34	78.8	69.6
07891	25	34	83.6	70
Kagome 70	23	29	81.4	73.1
Kagome 77	23	29	79.8	73.4
Total	542.0	680.5	1769.3	1587.3
Average	24.6	30.9	80.42	72.2
Difference	6.3		8.2	

sing which can be attributed to maturity and varietal differences.

Regression analysis of the standard curves developed at each time interval of heating showed that the TCI values gave the highest coefficients of correlation, followed by the Agtron E-5. Hunter a/b ratios gave lower levels of correlation, although significant at the 5% level or above.

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Effects of Concentration and Reconstitution on Tomato Juice Quality

HASAN FENERCIOGLU and W. A. GOULD[1]

INTRODUCTION

Tomatoes are the leading processed vegetable, in terms of per capita consumption, in the United States. Among processed tomato products, tomato juice is widely consumed as a breakfast juice or an appetizer served at any meal of the day. Contribution of tomato juice to the human diet is of prime importance (1).

During the past year, the Food and Drug Administration issued a number of temporary permits to tomato processors to test market tomato juice from concentrate in order to determine consumer acceptance of the product. Concentrated tomato juice has the advantages of being relatively resistant to chemical and microbiological spoilage due to lower water activity, being lighter in weight, and requiring less storage space and less packaging material than the single strength tomato juice. In addition, economies and cost savings in manufacturing, transporting, and storing tomato juice in the concentrated form might serve the best interest of the consumer.

This study was designed to find out the effects of concentration and reconstitution upon the color, ascorbic acid, pH, and total acidity of tomato juice.

MATERIALS AND METHODS

Machine harvested tomatoes of 19 cultivars were processed into regular single strength tomato juices and tomato concentrates. Unit operations involved in single strength tomato juice process were washing, chopping, preheating to 190-200° F, extracting through 0.023-inch screen, sterilization at 252° F for 42 sec, cooling to 200° F, filling in 303 x 406 enamel cans with added 30-grain NaCl salt tablets, closing, and cooling to 100° F prior to casing and storage. Tomato concentrates were made from the same juice for each cultivar by using 50 gallons of the extracted juice prior to sterilization. The juice was vacuum concentrated to 20% ± 0.5% soluble solids under a vacuum of 28 inches at 140° ± 3° F. The vacuum was broken and the temperature of the product was raised to 170° F. Immediately after, the product was filled in 303 x 406 enamel cans, steam-flow closed, inverted, and air cooled. The cans were held at room temperature until analyzed.

Reconstituted juice samples were prepared from concentrates by diluting the concentrated sample to the soluble solids content of the respective single strength tomato juice sample. A measured quantity of distilled water was added to the concentrate in a beaker and mixed with a spoon, while care was taken to minimize incorporation of air to the juice.

Both single strength and reconstituted tomato juice samples were analyzed for color, ascorbic acid, pH, and total acid by using previously described methods (2) without any modification after 1 month from processing.

RESULTS AND DISCUSSION

Color, ascorbic acid (Vitamin C), pH, and total acid values for single strength tomato juice (SSJ) and reconstituted tomato juice (RJ) samples are shown in Table 1. The results indicated that color of SSJ and RJ samples of the same cultivar as measured by TCM (tomato color) on a Hunter Color and Color Difference Meter D25D3A or by an Agtron E-5 instrument did not differ much from each other. This shows that effect of low concentration

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temperature (140° F) for a long period of time (75 min) on the color of tomato juice was about the same as that of high sterilization temperature (252° F) for a much shorter time period (42 sec).

Reconstituted tomato juice samples of all cultivars were higher in ascorbic content than their respective single strength tomato juice samples. The phenomenon may be explained by reduced thermal degradation and reduced oxidation of ascorbic acid during processing at lower temperatures and under vacuum, respectively. Therefore, vacuum concentration might be taken as an advantage to improve the nutritional quality of tomato juice.

The pH and total acid values of reconstituted tomato juice samples were found to be higher than their respective single strength tomato juice samples. In fact, lower pH values are expected with any increase in total acid content. However, increases in pH values of reconstituted tomato juice samples might be attributed to contribution of — OH ions by distilled water of 7.5 to 8.0 pH used for reconstitution. The high sterilization temperature causing the

TABLE 1.—Color, Vitamin C, pH, and Total Acid Values of Single Strength (SSJ) and Reconstituted (RJ) Tomato Juice Samples.

Cultivar	Product	Color		Vit. C	pH	Total Acid
		TCM	E-5	mg/100 ml		percent
Chico III	SSJ	72.2	31	10.4	4.40	0.41
	RJ	71.5	29	15.9	4.42	0.61
Campbell 37	SSJ	72.1	29	12.0	4.44	0.43
	RJ	73.0	27	17.0	4.50	0.51
H2867 (Heinz)	SSJ	71.7	30	14.8	4.40	0.47
	RJ	72.2	29	14.0	4.44	0.60
Sea 77	SSJ	72.0	31	11.6	4.52	0.34
	RJ	70.0	30	15.9	4.56	0.35
07630	SSJ	71.5	32	11.6	4.48	0.39
	RJ	71.1	31	14.1	4.54	0.38
07663	SSJ	70.7	30	13.5	4.46	0.42
	RJ	72.0	28	17.7	4.52	0.44
07667	SSJ	71.7	30	9.2	4.44	0.46
	RJ	73.0	28	14.7	4.50	0.49
07681	SSJ	75.3	29	13.2	4.54	0.32
	RJ	74.2	27	16.5	4.62	0.36
07721	SSJ	71.1	32	11.6	4.48	0.38
	RJ	72.3	29	15.3	4.54	0.43
07723	SSJ	72.2	32	10.7	4.48	0.40
	RJ	70.7	30	14.4	4.52	0.42
07724	SSJ	75.5	28	16.8	4.58	0.34
	RJ	74.0	27	18.0	4.62	0.42
07731	SSJ	76.2	27	16.5	4.55	0.33
	RJ	76.1	25	21.0	4.56	0.42
07759	SSJ	71.2	32	11.9	4.52	0.41
	RJ	71.4	28	16.2	4.54	0.49
076122	SSJ	74.0	29	12.9	4.44	0.39
	RJ	74.7	26	16.2	4.50	0.44
07770	SSJ	72.2	31	15.9	4.46	0.36
	RJ	72.5	28	18.6	4.62	0.38
07872	SSJ	69.6	34	10.8	4.40	0.43
	RJ	69.2	32	15.6	4.48	0.49
07891	SSJ	70.0	34	12.9	4.45	0.39
	RJ	71.4	30	15.6	4.52	0.43
Kagome 70	SSJ	73.1	29	16.2	4.38	0.42
	RJ	72.4	29	20.4	4.40	0.52
Kagome 77	SSJ	73.4	29	20.7	4.40	0.42
	RJ	73.6	28	22.2	4.42	0.51
$\bar{X}$	SSJ	72.4	30.5	13.3	4.46	0.40
	RJ	72.4	28.5	16.8	4.52	0.46

breakdown of acidic groups of tomato juice was thought to be responsible for lower total acid content values in single strength tomato juice samples.

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Homogenized Tomato Juice Mold Counts and Process Identification

NICHOLAS N. KALLAS and W. A. GOULD[1]

INTRODUCTION

Recently widespread industry concern has surfaced over the Food and Drug Administration's (FDA) mold and rot fragment count defect action levels (DALs) and methodology as related to comminuted tomato products (6). This concern has been manifested by various tomato product comminution techniques that can and do result in finished products containing mold levels above current DAL guidelines, even though the products are manufactured from tomatoes as concentrate which would be considered acceptable if manufactured by conventional processing techniques.

Commercially, tomato juice is manufactured by pulping or finishing extraction equipment. Additionally, several processors employ a homogenization process to reduce settling and to produce a thicker-bodied tomato juice (5). The homogenization process is a mechanical reduction and dispersion of a solid (or immiscible liquid) in a liquid (8). But while homogenization reduces the average tomato particle size, it also causes breakage and dispersion of mold filaments. Consequently, due to the apparent design of the Howard mold counting method which requires the examination of a standard microscopic field for the presence or absence of a specified minimum aggregate length of mold filaments, the mold count, expressed as a positive field percentage, may be significantly influenced by the degree of breakage or dispersion of mold filaments (4) produced by homogenization.

The National Food Processors Association has found homogenization pressures between 800 and 1200 psi to increase mold counts 60 to 100%, while reducing rot fragment counts to zero (9). Eisenberg (4) stated that mold counts generally increase with increasing homogenization pressures, but the increase in mold counts reaches a plateau at high pressures (approximately 2200 psi) and even may tend to decrease with homogenization pressures beyond these levels. He also reported that comminution generally causes a decrease or insignificant change in the rot fragment count. Troy (9) stated that the effect of homogenization on mold counts in tomato juice is irregular due to the character of the mold, although he reported the mold count is usually higher after homogenization.

Recently, Welch Foods (2) recommended that an allowance in the mold count DALs for tomato juice of 21% prior to homogenization be made 42% after homogenization. But due to the tolerance levels of the present DALs, such a change is unnecessary. FDA's recognition that highly variable mold count results can be obtained due to different types of homogenization equipment, different operating conditions, *i.e.* pressure, of the same equipment, and different types of mold has led to devising the DALs in the only logical manner possible. The mold count DAL for homogenized tomato juice is sensibly stated as follows (9): adequate allowances will be made in applying the tomato juice tolerance (of 21%) to those articles which have been subjected to a homogenization process.

OBJECTIVES

1. To determine the effect of pulper screen size and homogenization on mold and rot fragment counts in tomato juice.
2. To investigate an objective means of process identification to determine homogenized from non-homogenized tomato juice.

MATERIALS AND METHODS

Tomato juice was manufactured from known initial rot level raw product qualities using a 190° F break temperature, two different pulper screen sizes

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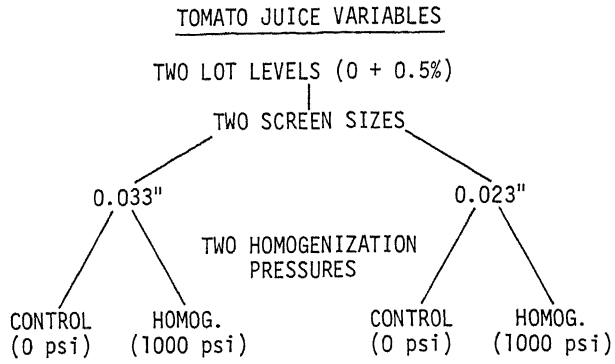
(0.023 and 0.033 inch performations), and two different homogenization pressures (0 and 1000 psi). Two initial rot levels (0% and 0.5% cut-out rot by weight) were utilized. Approximately 100 lb of raw product were used per treatment.

After treatment the juice was collected, canned, and heat processed in boiling water for 60 minutes. At each initial rot level, five samples per treatment were evaluated. Thus, each bar on the following mold and rot fragment figures represents the average of five samples. On the process identification table, each treatment represents the average of 10 samples. Produce evaluation included a 100 field, four slide Howard mold count, a rot fragment count, and a process identification investigation. This investigation consisted of a settling experiment and a microscopic observation for the presence or absence of intact flesh cells. The settling experiment (7) involved placing 8 ml of tomato juice in 92 ml of deaerated H_2O in a 100 ml graduated cylinder. This mixture was tipped up and down five times but not shaken, and the ml graduation of the settled juice was recorded after 10 minutes. Three individual settling experiments were performed per sample. All statistical analyses are by Duncan's multiple-range test at the 0.01 level of significance unless otherwise indicated.

A schematic flow outline of the study is shown below:

LOT (Two initial rot levels: 0 and 0.5% cut-out rot, by weight)
↓
SOAK AND SPRAY WASH
↓
SORT
↓
CHOP (Fitzpatrick Mill Model D fixed impact edge blades through 1/2-inch screen No. 5 at 2000 RPM blade speed)
↓
HOT BREAK (190° F)
↓
PULP (Langsenkamp laboratory size pulper, 0.023 and 0.033 inch perforation screens, 1650 RPM speed, 1/8 inch clearance, 3/8 inch lead)
↓
HOMOGENIZATION (Cherry Burrel Corporation, 0 + 1000 psi pressure, JR 75 stellar series junior sanitary viscolizer)

(All processing occurred at The Ohio State University, Department of Horticulture, Food Processing and Technology Pilot Plant.)



RESULTS AND DISCUSSION

At the 0% initial rot level, no significant differences occurred between screen sizes and homogenization pressures for both the mold and rot fragment counts (Figs. 1 and 3). This occurred because all sound tomatoes were used and only low counts were obtained. However, it is important to note that even though all visually sound product was used, a Howard mold count and a rot fragment count, although small, were obtained.

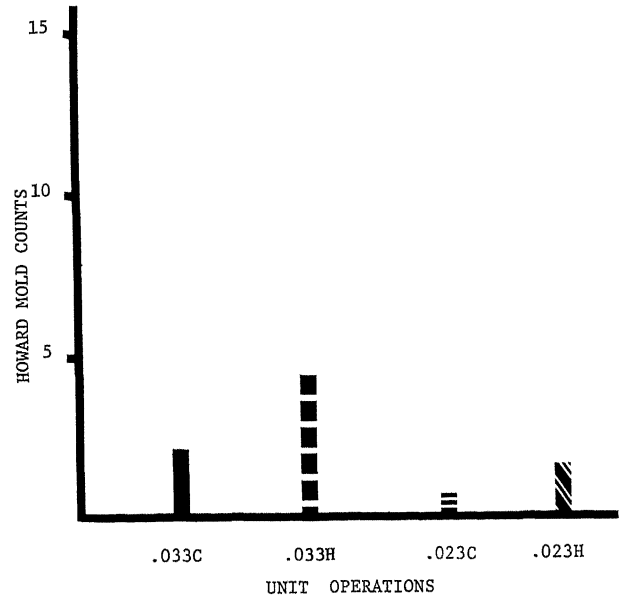


FIG. 1.—Tomato juice average mold counts: 0% initial rot.

TABLE 1.—Tomato Juice: Process Identification.

Treatment	Flesh Cell	Settling (ml) Mean	S.D.	Differences (.05)
.033 Homog	—	92.6	7.1	A
.023 Homog	—	87.4	10.0	B
.023 Control	+	24.6	2.5	C
.033 Control	+	23.2	2.6	C

(—) No Intact Flesh Cells (+) Intact Flesh Cells

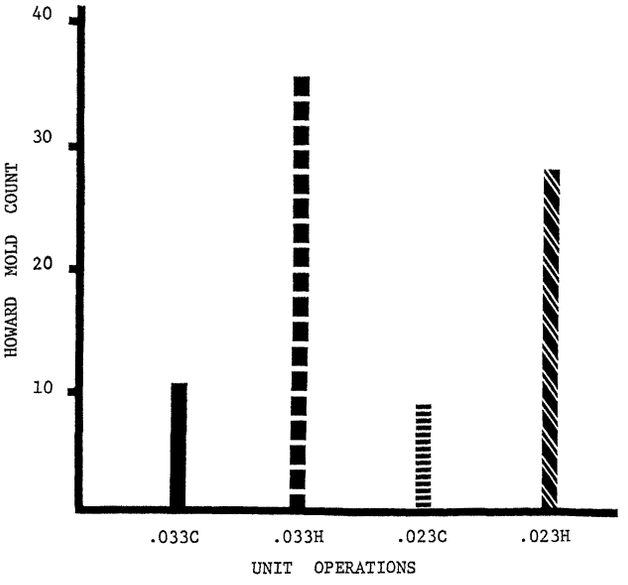


FIG. 2.—Tomato juice average mold counts: 0.5% initial rot.

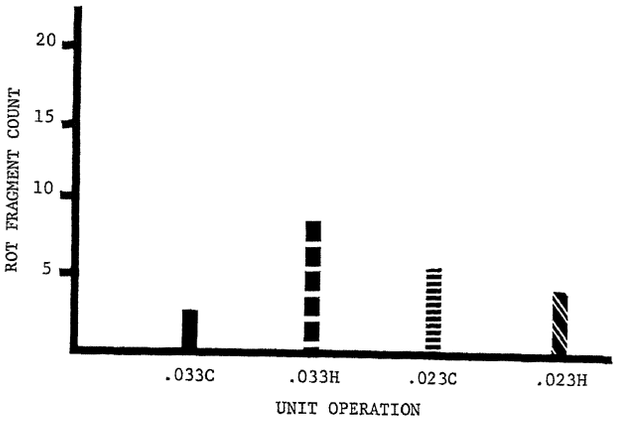


FIG. 3.—Tomato juice average rot fragment counts: 0% initial rot.

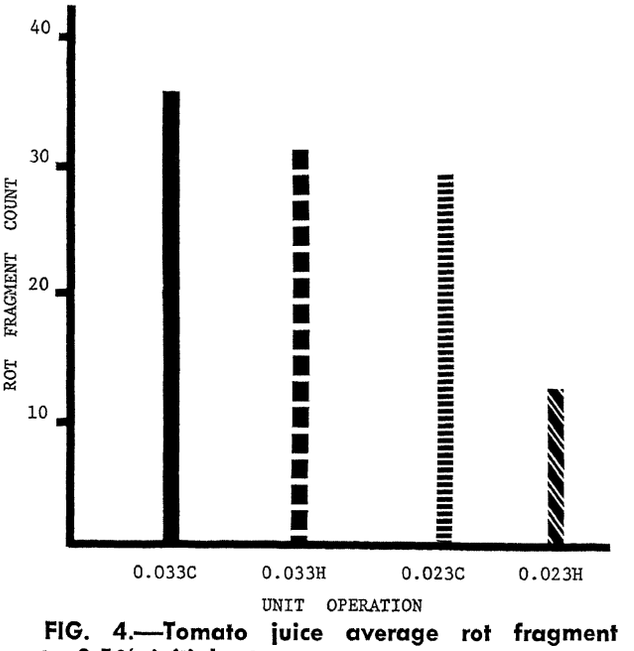


FIG. 4.—Tomato juice average rot fragment counts: 0.5% initial rot.

At the 0.5% initial rot level, significant differences in the Howard mold count were obtained between the control (0 psi) and the 1000 psi homogenization treatment for both screen sizes (Fig. 2). At both screen sizes, homogenization produced a more than 200% increase in mold count (Fig. 2).

Although the rot fragment counts for the homogenized samples at the 0.5% initial rot level were slightly lower than the non-homogenized samples, no significant difference in rot fragment count was observed (Fig. 4). Also, no significant difference in either the mold or the rot fragment count was observed between the two screen sizes utilized (Figs. 2 and 4).

At the 0.5% initial rot level, homogenization increased the mold count above the 21% DAL level employed for non-homogenized tomato juice (Fig. 2). However, it appears that these increases are within the "adequate allowance" tolerance accorded tomato juice subjected to a homogenization process. But the question arises, how can it be determined, after-the-fact, whether the product has been subjected to a homogenization process?

Eisenberg (4) stated that data to determine the effect of a particular process on mold counts are useless in the absence of a practical means of recognizing the process and its effect on mold filament dispersion by an objective examination of the product. He (4) further stated that process recognition can be obtained by the inverse relationship between the mold and the rot fragment count which results from particle size reduction. However, no standard or DAL exists for rot fragments in tomato juice. Also, the merit of the rot fragment count has been questioned recently by the National Food Processors Association *Ad Hoc* Committee on Mold in Tomato Products (6) due to the highly variable results obtained with the method.

Therefore, the authors felt that an objective and practical process identification procedure other than the inverse relationship between the mold and the rot fragment count should be investigated. These results (Table 1) indicate that both the microscopic examination for flesh cell intactness and the settling experiment provide great potential as means of process identification. The limitation is recognized that these identification methods were evaluated on a limited number of samples, with only one type of homogenizer, and at

only one homogenization pressure, and that an evaluation of a wide range of commercial samples produced under varying operating conditions is required before acceptance.

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Effects of Comminution on Mold in Tomato Products

NICHOLAS N. KALLAS and W. A. GOULD[1]

INTRODUCTION

Recently widespread industry concern has surfaced over the Food and Drug Administration's (FDA) mold and rot fragment count defect action levels (DALs) and methodology as related to comminuted tomato products. This concern has been manifested by various tomato product milling techniques that can and do result in finished products containing mold levels above current DAL guidelines, even though the products are manufactured by conventional processing techniques.

From a regulatory standpoint, finished product mold and rot fragment counts are used as an indication of the quality, as related to fungal rot, of the raw tomato commodity. But a National Food Processors Association *Ad Hoc* Committee on Mold in Tomato Products (2) has declared that present mold and rot fragment count guidelines as applied to comminuted tomato products are inadequate as an indication of raw fruit quality.

This problem has occurred due to the apparent design of the Howard mold and rot fragment counting methods. The Howard method requires the examination of a standard microscopic field for the presence or absence of a specified minimum aggregate length of mold filaments. Consequently, the Howard mold count, expressed as a positive field percentage, may be significantly influenced by the degree of breakage or dispersion of the mold filaments (1). In addition, the rot fragment count, determined by a physical separation according to size, may also be significantly influenced by the degree of size reduction or breakage of the rot fragments. Unfortunately, neither method measures the specific amount of mold or rot present. This study was undertaken in an effort to determine the effects of comminution on mold counts of tomato products.

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MATERIALS AND METHODS

Tomato concentrate (20% soluble solids) was manufactured from known initial rot level raw product qualities using a 0.033 inch pulper screen and a 190° F break temperature. Initial rot levels included 0.25, 0.50, and 0.75% cut-out rot by weight. Approximately 1,000 lb of raw product were used per replication. Post-concentration treatments included the following: control (direct from vacuum concentrator), Urschel Comitrol, Fitzpatrick Mill, homogenization (two pressures: 1000 psi and 4000 psi), and pulper (two screen sizes: 0.023 and 0.033-inch perforations). Approximately 5 to 10 gallons of concentrate were passed through each machine at approximately 150-160° F. The concentrate was then collected, canned, and heat processed in boiling water for 60 minutes.

Three replications at each initial rot level and five samples per treatment were evaluated. Thus, each bar on the following figures represents the average of 15 samples. Product evaluation included a 100 field, four slide Howard mold count and two separate rot fragment counts. All statistical analyses are by Dun-

can's multiple-range test at the .05 percent level of significance.

A schematic flow outline of the study follows:

LOT (Three initial rot levels: 0.25%, 0.50%, and 0.75% cut-out rot by weight)
|
BREAK (190° F, Model D Fitzpatrick Mill fixed impact edge blades through 1/2-inch screen No. 5 at 2000 RPM blade speed)
|
PULP (0.033 inch screen, 1650 RPM speed, 1/8 inch clearance, 3/8 inch lead, Langsenkamp laboratory size pulper)
|
CONCENTRATE (20% soluble solids, 150-160° F, Style VT vacuum kettle, Hamilton Kettles under 28 inch vacuum)
|
FINISH OR MILL TREATMENTS

1. CONTROL: Direct from concentrator (described above)
2. URSCHEL COMITROL: Model 1700 Comitrol, 200084 micro-cut head, 9540 RPM impeller speed, 200 blades, 0.010 inch distance between blades
3. FITZPATRICK MILL: Model D, screen size #1, sharp concave knife edges, at 2000 RPM, 0.020 inch screen
4. HOMOGENIZATION: JR 75 stellar series junior sanitary viscolizer, Cherry Burrel Corporation, two pressures: 1000 and 4000 psi
5. PULPER: Two screen sizes: 0.023 and 0.033 inch perforations, 1650 RPM impeller speed, Langsenkamp laboratory size pulper (as explained above)

(All processing occurred at The Ohio State University, Department of Horticulture, Food Processing and Technology Pilot Plant)

TOMATO CONCENTRATE VARIABLES

THREE INITIAL ROT LEVELS (0.25%, 0.50%, and 0.75%)

SEVEN POST-CONCENTRATION TREATMENTS

CONTROL | 0.033 PULPER | 0.023 PULPER | FITZ. MILL | URSCHEL COMITROL | 1000 psi HOMOG. | 4000 psi HOMOG.

RESULTS AND DISCUSSION

The following conclusions can be drawn from the data collected under these experimental pilot plant conditions:

No significant differences between the control and the pulper samples at either screen size and at all initial rot levels occurred for both the mold and the rot fragment counts (see Figs. 1-6). This indicates that conventional processing of tomato concentrate does not change the mold or the rot fragment count. However, a trend of significantly increased Howard mold counts occurred after milling and homogenization at all three initial rot levels, indicating mold counts are increased by comminution due to breakage and/or dispersion of mold filaments (Figs. 1, 2, and 3).

All rot fragment counts at all three initial rot levels were either significantly decreased or unchanged by the various processing operations except for the Urschel Comitrol milling (Figs. 4, 5, and 6). At two initial rot levels (0.25% and 0.75%), the rot fragment count was significantly increased by Urschel Comitrol milling when compared with all other treatments (Figs. 4 and 6). At the other initial rot level (0.5%), Urschel Comitrol milling brought about no

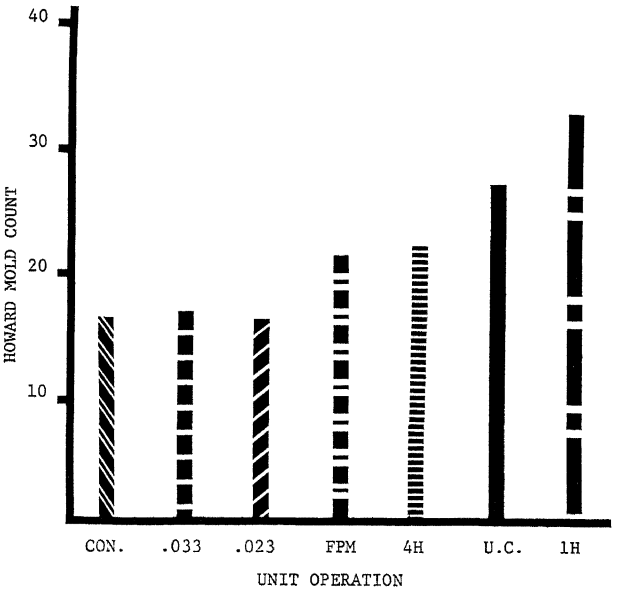

FIG. 1.—Tomato concentrate average mold counts: 0.25% initial rot.

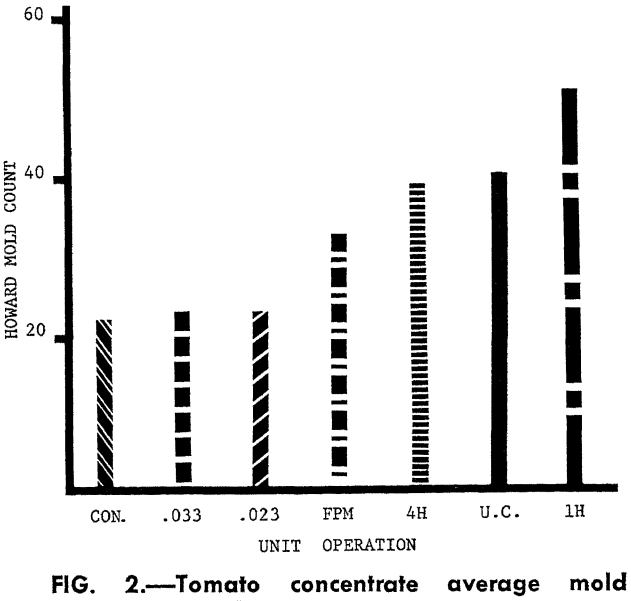

FIG. 2.—Tomato concentrate average mold counts: 0.50% initial rot.

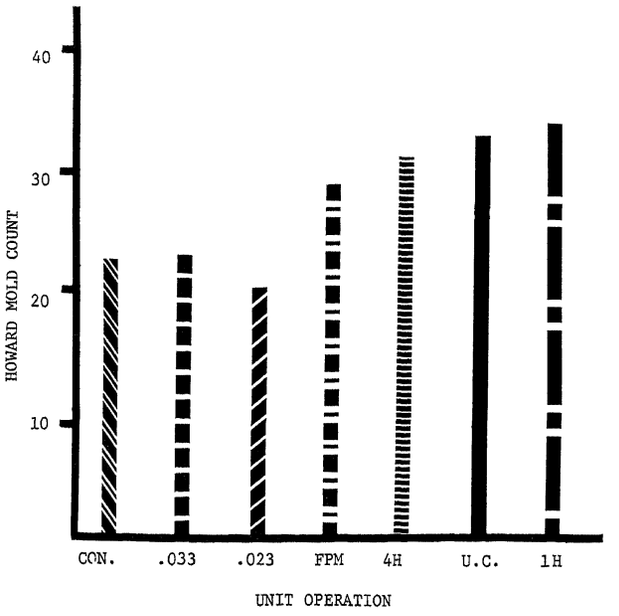

FIG. 3.—Tomato concentrate average mold counts: 0.75% initial rot.

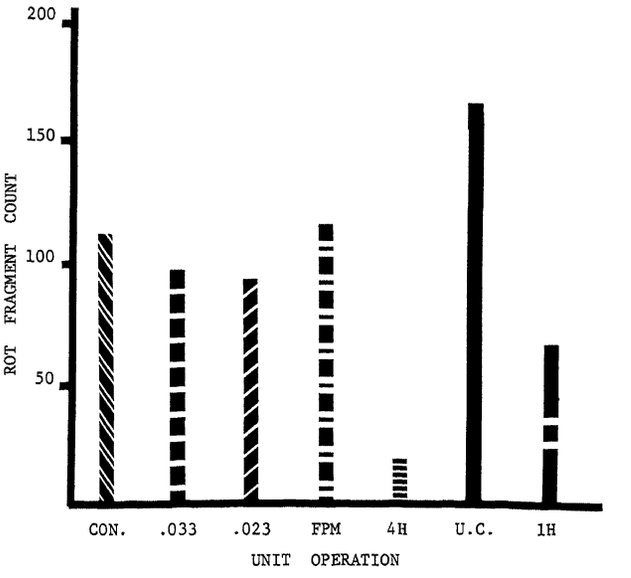

FIG. 4.—Tomato concentrate average rot fragment counts: 0.25% initial rot.

significant change in the rot fragment count from the control or the conventionally made concentrate (Fig. 5). The precise cause of this rot fragment count variation with Urschel Comitrol milling is not known. Nevertheless, Urschel Comitrol milling can and does increase the rot fragment count (Figs. 4 and 6).

In summary, passing a product through a particular comminutor (mill) does not change the actual amount of mold or rot present in that product. But due to breakage, dispersion, and/or reduction in mold filament size, both the Howard mold count and the rot fragment count can be significantly affected as mentioned.

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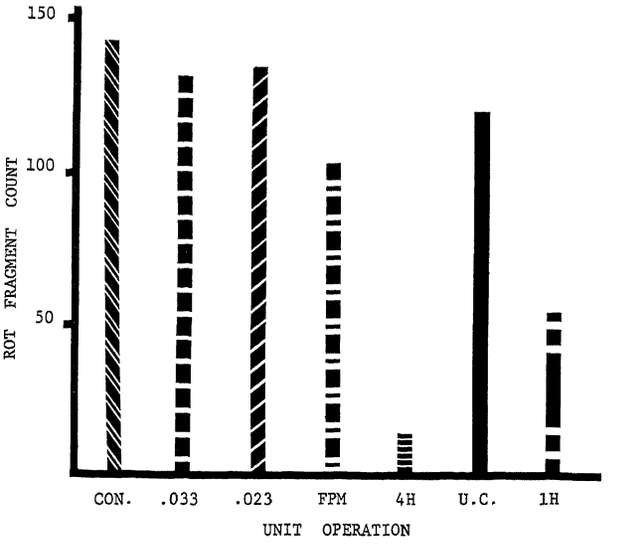

FIG. 5.—Tomato concentrate average rot fragment counts: 0.50% initial rot.

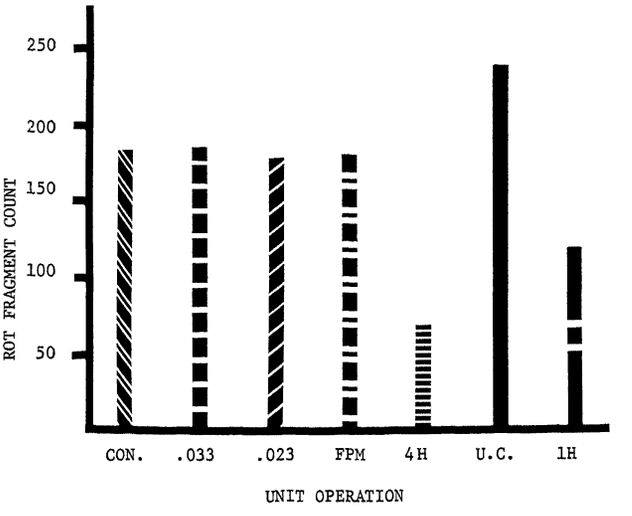

FIG. 6.—Tomato concentrate average rot fragment counts: 0.75% initial rot.

Use of Diacetylfluorescein to Monitor Tomato Juice for Microbial Contamination

RICHARD BASEL and W. A. GOULD[1]

INTRODUCTION

Aseptic storage of tomato concentrates requires a sensitive monitoring technique for the detection of microbial contamination. One sensitive method for monitoring aseptically stored tomato paste is to detect the presence of diacetyl or acetylmethylcarbinol by colorimetry or GLC. This technique can detect levels of microbial spoilage in 4-12 hours at levels greater than 4 x 10^5 cells/g of paste. While this method can yield results far more quickly than plate counts, this method is labor intensive. It also does not quantitate whether contamination occurred before processing or whether viable metabolically active organisms are present (2).

Diacetylfluorescein (DAF) is a colorless, nonfluorescent compound that has been used as a vital stain for bacteria, yeast, and fungi (1, 3, 4). When endogenous enzymes, *i.e.,* lipases, esterases, or proteases, hydrolyze off the acetyl groups, the compound becomes strongly fluorescent as shown in Figure 1 (1). Since all organisms possess these enzymes, it is obvious that accumulation of these hydrolysates could be used as an index of microbial growth in a thermally processed product provided that autohydrolysis can be eliminated from the reading by zeroing with a standard. In this study, preliminary data on a monitoring technique based on DAF will be cited.

MATERIALS AND METHODS

Clostridium pasteuranum and *Lactobacillus plantarum* were obtained from the Microbiology Department at The Ohio State University. *Saccharomyces cerevesiae* var. *ellipsoideous* (Montrachet 522) was obtained from Dr. J. F. Gallander, Dept. of Horticulture, Ohio Agricultural Research and Development Center, Wooster.

Cultures were inoculated into sterile tomato juice (pH 4.3) and incubated at 20° C. At the end of incubation, half of the sample was autoclaved at 121° C for 15 minutes or a sterile control was used from the same lot of tomato juice. To the tomato juice was added 10% sterile Tris stock solution (24.2 g Tris [hydroxymethyl] aminomethane. This addition adjusted the pH to 7.5. Ten-fold dilutions were made into 100 ml physiological saline and Tris-HCl buffer (pH 7.8 and 0.05 M) 5:1 (v:v).

In order to determine which emulsifiers gave the best results, 1% acetone and 1% of an emulsifier solution were added (1 ml H_2O as control, 1 ml butylated hydroxytoluene (BHT) as antioxidant control, 1 ml Tween-80, 1 ml Triton X 100, or 1 ml of 1 M sodium dodecylsulfate [SDS]). The sample was shaken vigorously and the sample was allowed to stand 15 minutes to permit time for the disruption of cells. At the end of 15 minutes, 1 ml of 0.001 g/ml DAF was added. The DAF should be freshly recrystallized in methanol to purify it, and the stock solution made daily to insure purity. At various incubation times, the samples were filtered through a Whatman No. 1 filter and read on an Aminco 24-7439 fluorocolorimeter (Silver Springs, Md.) equipped with a 525 nm barrier filter.

SDS was used as the emulsifier for testing tomato juice for contamination. All of these measurements were made after zeroing against an autoclaved tomato juice blank. Up to the final filtering before reading, all operations were done using aseptic technique to eliminate false positive results due to contaminated equipment and reagents.

Plate counts were obtained by plating on tomato juice agar (Difco) for *S. cerevesiae* and *L. plantarum.* In the case of *C. pasteuranum,* counts were made in deep tomato juice agar tubes.

RESULTS AND DISCUSSION

It was found that DAF degrades autohydrolytically very quickly. To test which is the best emulsifier, various ones were used. In addition, BHT was used to test whether antioxidants could inhibit degradation. Results of a 12-hour incubation with these emulsifiers are shown in Table 1. It was found that there is reduced autohydrolysis with the addition of antioxidants. This result may lead to the development of a revised assay procedure with more limited autodegradation of substrate.

There was no significant change in autohydrolysis as compared to the control using Tween-80 or SDS. Triton X 100 exhibits greatly increased autohydrolysis. In order to get significant results, the emulsifier must inhibit binding of the fluorescein compounds while maximizing enzymatic activity. SDS was the only emulsifier with a positive spoilage index (positive fluorescence compared to a control read against the sterile blank). The sterile blanks did not include sterile tomato juice whereas the sample treatments

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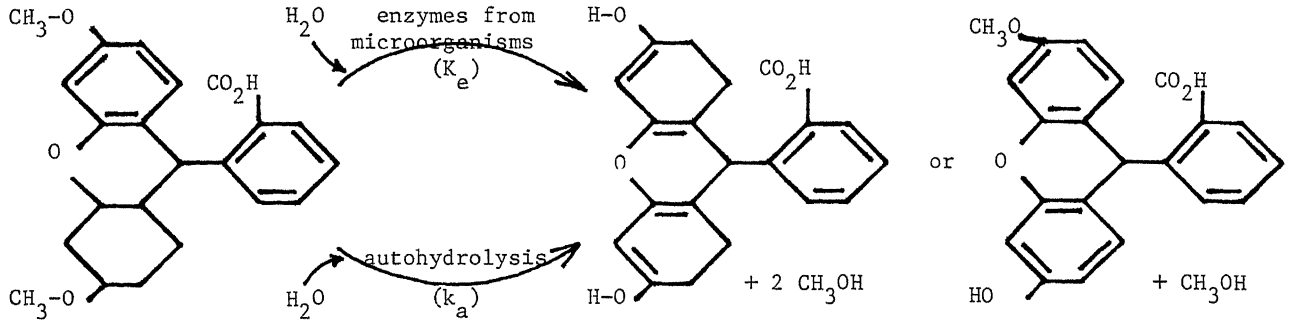

$$\frac{dX}{dt} = (k_a + k_e)\,[X]$$

f auto catalysis is eliminated by a reference sample not having enzymatic activity, the equation can be simplified

$$\text{to the } \frac{dX}{dt} = (k_e\,[X]\,)^n$$

FIG. 1.—Mechanism of diacetylfluorescein microbial contamination of tomato products assay.

TABLE 1.—Incubation of Emulsifiers for 12 Hours with Acetone and Diacetylfluorescein.

Emulsifier	Inoculated with 1% S. cerevisiae Contaminated Tomato Juice	Mean Fluorescence	Spoilage Index*
Control	no	4200	
	yes	3700	— 500
BHT Control	no	2850	
	yes	2850	0
SDS	no	4400	
	yes	6800	+ 2400
Tween-80	no	4400	
	yes	3900	— 500
Triton X 100	no	9400	
	yes	8200	— 1200

*Spoilage index is the inoculated fluorescence minus none inoculated fluorescence.

TABLE 2.—Dilution Method for Determining Contaminated Tomato Juice by the Hydrolysis of Diacetylfluorescein.

Organism	Dilution	Cell Count/ml	Relative Fluorescence After 1 Hour*
C. pasteuranum	10^0	1.2×10^5	(—)
	10^{-1}	1.2×10^4	900
	10^{-2}	1.2×10^3	230
	10^{-3}	1.2×10^2	0
L. plantarum	10^0	1.6×10^6	1200
	10^{-1}	1.6×10^5	180
	10^{-2}	1.6×10^4	1400
	10^{-3}	1.6×10^3	590
S. cerevesiae	10^0	3.1×10^3	(—)
	10^{-1}	3.1×10^2	245
	10^{-2}	3.1×10^1	90
	10^{-3}	3.1×10^0	0

*Variability $\pm$ 70 (greater than a difference of 70 gives a $p > .05$ of the product being contaminated).

contained a 10^{-2} dilution of tomato juice visibly contaminated with *S. cerevesiae*.

One possible reason for the reduced fluorescence with the contaminated samples may have been binding to the insoluble solids. If a detergent is strong enough to inhibit binding, a positive spoilage index results. The reason why BHT exhibited a spoilage index of zero is unknown, although it may be due to binding to sites related to fluorescein binding. It is also possible that the dilution used may dilute an inhibitor of DAF autohydrolysis and/or a quenching compound in tomato juice. The data in Table 2 show this effect as a large deviation in fluorescence measured from the expected changes due to dilution. As the tomato juice is further diluted, there is an increase in the relative amount of fluorescence. Therefore, it is imperative that a dilution series be used when assaying tomato products.

In Table 2 the results of three of the many contaminants tested are shown. Bacteria can be consistently detected in levels greater than 10^3 vegetative cells/ml. Vegetative cells of yeast/ml greater than 10^1 to 10^2 can also be detected. Even lower counts have been detected for fungi. This result is misleading due to the long average mycelium sizes. In this case it may be more appropriate to think in terms of total mold biomass instead of just cell counts.

Highly contaminated samples with approximately 10^5 or more bacteria/ml may be evaluated without employing a fluorimeter. This is accomplished by comparing a sterile blank and the unknown sample under a long wave UV lamp. If the sample is highly contaminated, either the sample and/or dilutions will fluoresce much brighter than the control.

This method has potential as a routine method for evaluating thermally processed stored food for contamination. Correlation between cell counts and fluorescence depends on the metabolic state of the vegetative cells, product attributes (such as pH, soluble solids, salt, and inhibitors) and the strain of microorganism in the tomato product. Therefore, this method is not anticipated as a method for quantitating absolute cell numbers. This method is a way of approximating microbial metabolic activity. Variability and acceptable ranges for foods should be assessed based upon the instrument used and product employed.

This method will be evaluated in the future for other food products. It is hoped that this method will enable detection of contamination in other food systems that are both canned and aseptically stored.

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The Effects of Microbial Load on Anaerobic Spoilage of Various Tomato Juice Formulations

RICHARD BASEL and W. A. GOULD[1]

INTRODUCTION

Aseptic tomato storage methods include both storage (1, 4) and packaging systems (2). Since tomato juice cocktails are an important and rapidly expanding product line for many companies, the dynamics of possible spoilage in these formulations is important. Aseptic packaging of these products from bulk stored concentrates is desirable for year-round processing of these products.

Before a processor designs a packaging system, contamination dynamics should be investigated. Once the problematic organisms are identified and their growth characteristics are determined, quality control procedures can be devised to prevent these contaminants. In order to better understand problematic organisms, the smallest microbial load producing anaerobic spoilage at differing tomato juice formulations has been determined. Results of three organisms will be shown and the results from other less problematic organisms will be briefly described.

MATERIALS AND METHODS

Cultivation of Spoilage Organisms

Lactobacillus plantarum and *Leuconostoc mesenteroides* were obtained from the Microbiology Department at The Ohio State University. *Saccharomyces cerevesiae* var. *ellipsoideous* (Montrachet 522) was obtained from Dr. J. F. Gallander, Dept. of Horticulture, Ohio Agricultural Research and Development Center, Wooster.

The microorganisms were acclimatized in tomato juice supernatant (tomato juice serum). This serum was prepared by centrifugation at 5,000 g for 10 minutes in a Sorvall RC-2 centrifuge using a HB-4 head. Log phase cultures were diluted in tomato juice. Log phase growth of cultures for inoculation was followed by watching for an increase in turbidity. Inoculation size was approximated by measuring optical density of the stock at 620 nm and confirming the exact inoculum size by plate counts.

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Tomato Juice Formulations

Tomato juice formulations used in this study are presented in Table 1.

Tomato juice was tested at two temperatures, tomato juice with condiments, tomato concentrate to test the effect of the sugar on osmotic pressure, tomato with a higher pH and the effect of ethanol was tested with and without spices added. Ten ml aliquots of a tomato juice formulation were placed into 18 X 100 mm test tubes deaerated by heating, and cooled to 45° C. Tomato juice samples having 10% ethanol were deaerated, gently mixed with the ethanol while warm, and aliquots were carefully transferred with as little oxygen uptake as possible.

Inocula of microorganisms were suspended in 0.1 ml tomato juice. Tubes were inoculated with one of three inoculum sizes (using three consecutively higher logarithmic dilutions each increasing by one power) as determined by plate counts. Then 3 ml of sterile 0.5% sodium thioglycolate with 1% agar was layered on top of the tomato juice culture. After the agar had solidified, the tubes were mixed without disturbing the agar plug by rolling them through the palms.

Plate Counts of Microbial Growth in Tomato Juice Formulations

At 1, 2, 4, 8, and 16 days after inoculation, the number of organisms/ml was determined by dilution pour plating. A 1% solution of peptone was used for all dilution bottles. Yeasts were plated on Potato Dextrose Agar (Difco). Lactic acid bacteria were plated on Tomato Juice Agar (Difco).

TABLE 1.—Tomato Juice Formulations Tested for Growth by Various Inocula.

Tomato Juice Formulations	pH	Percent Total Acidity	Refractive Index	Incubation Temperature °C
Tomato juice	4.3	0.36	1.3425	37
Tomato cocktail	4.1	0.39	1.3422	37
Tomato juice and 10% ethanol	4.4	0.35	1.3456	37
Tomato cocktail and 10% ethanol	4.4	0.35	1.3451	37
Tomato juice with higher pH	4.8	0.29	1.3425	37
Tomato concentrate	4.3	1.11	1.3586	37

TABLE 2.—Growth of Saccharomyces cerevesiae in Various Tomato Juice Formulations (Mean Plate Counts).

Tomato Juice Formulation	Inoculum Size	Days After Inoculation				
		1	2	4	8	10
Tomato juice	5.0 X 10^3*	5.8 X 10^7	8.9 X 10^8	8.3 X 10^8	1.7 X 10^8	9.3 X 10^7
	5.0 X 10^2	4.9 X 10^7	8.5 X 10^5	8.4 X 10^8	7.1 X 10^8	2.0 X 10^7
	5.0 X 10^1	6.0 X 10^7	7.8 X 10^8	5.0 X 10^8	1.2 X 10^7	7.5 X 10^6
Tomato cocktail	5.0 X 10^3	5.7 X 10^7	8.7 X 10^8	6.1 X 10^8	5.7 X 10^8	1.7 X 10^7
	5.0 X 10^2	5.1 X 10^7	8.3 X 10^8	4.3 X 10^8	1.2 X 10^7	5.3 X 10^8
	5.0 X 10^1	7.4 X 10^7	8.6 X 10^8	4.3 X 10^8	1.2 X 10^7	1.6 X 10^7
Tomato juice with 10% ethanol	5.0 X 10^3	8.9 X 10^5	4.9 X 10^8	1.9 X 10^7	1.4 X 10^7	4.3 X 10^6
	5.0 X 10^2	8.3 X 10^3	1.4 X 10^3	8.4 X 10^5	6.5 X 10^7	1.3 X 10^6
	5.0 X 10^1	1.0 X 10^3	2.1 X 10^3	4.6 X 10^4	3.6 X 10^5	4.3 X 10^5
Tomato cocktail with 10% ethanol	5.0 X 10^3	7.4 X 10^5	3.1 X 10^8	5.8 X 10^7	4.6 X 10^7	9.7 X 10^6
	5.0 X 10^2	7.7 X 10^3	4.1 X 10^4	8.7 X 10^8	9.4 X 10^7	1.2 X 10^6
	5.0 X 10^1	1.0 X 10^3	6.4 X 10^3	5.5 X 10^4	3.5 X 10^7	4.2 X 10^6
Tomato juice with a higher pH	5.0 X 10^3	9.2 X 10^8	3.3 X 10^8	7.8 X 10^8	1.6 X 10^7	3.8 X 10^5
	5.0 X 10^2	8.5 X 10^8	8.2 X 10^8	6.7 X 10^8	9.4 X 10^7	1.3 X 10^6
	5.0 X 10^1	6.8 X 10^7	6.0 X 10^8	2.2 X 10^8	4.5 X 10^7	8.6 X 10^6
Tomato concentrate	5.0 X 10^3	9.5 X 10^8	8.7 X 10^5	3.7 X 10^8	2.4 X 10^8	8.6 X 10^6
	5.0 X 10^2	8.6 X 10^8	8.7 X 10^8	4.6 X 10^8	3.0 X 10^5	2.6 X 10^7
	5.0 X 10^1	5.6 X 10^8	4.5 X 10^8	6.6 X 10^5	6.4 X 10^7	2.9 X 10^6

*Organisms/ml.

Gas production was measured in mm in tubes with thioglycolate agar plugs. The gas was measured as the air space from the bottom of the agar plug to the top of the tomato juice culture.

RESULTS AND DISCUSSION

Saccharomyces cerevesiae, a yeast, grew very well on all the tomato juice preparations tested (Table 2). It grew to spoilage levels in all juice formulations with-

TABLE 3.—Gas Production by Saccharomyces cerevesiae in Tomato Juice Formulations.

Tomato Juice Formulation	Days after Inoculation	Inoculum size		
		5 X 10^3 cells/ml	5 X 10^2 cells/ml	5 X 10^1 cells/ml
Tomato juice	1	11 mm	10 mm	2 mm
	2	> 100 mm	> 100 mm	> 100 mm
Tomato cocktail	1	+	+	+
	2	> 100 mm	5 mm	2 mm
	3	> 100 mm	40 mm	32 mm
	4	> 100 mm	> 100 mm	> 100 mm
Tomato juice with 10% ethanol	1	1 mm		
	2	22.5 mm		
	3	27 mm		
	4	> 100 mm	+	
	5	> 100 mm	10 mm	+
	6	> 100 mm	12 mm	12 mm
Tomato cocktail with 10% ethanol	1			
	2	23 mm		
	3	25 mm		
	4	> 100 mm	+	
	5	> 100 mm	10 mm	+
	6	> 100 mm	12 mm	12 mm
Tomato juice pH 4.8	1	25 mm	10 mm	7.5 mm
	2	> 100 mm	> 100 mm	> 100 mm
Tomato juice concentrate	1	64 mm	7.4 mm	12 mm
	2	> 100 mm	> 100 mm	> 100 mm

in 24 hours. None of the other organisms studied grew nearly as well. In previous industrial experience with aseptic handling of tomato products, yeast spoilage was the most persistent problem encountered. Yeast did not appreciably alter the pH and total acidity. However, large amounts of gas were always associated with metabolism.

Inoculum size only slightly influenced gas production in tomato juice formulations without ethanol added (Table 3). With tomato juice and cocktail with 10% ethanol, the gas formation could be delayed for days by using an inoculation size of less than 500 organisms/ml. Nevertheless, gas production indicative of yeast spoilage eventually occurred with all treatments except where tomato juice was inoculated at 45° C.

From its apparent uninhibited growth in tomato juice preparations, it appears that even one organism would be effective in producing spoilage in a majority of cases. Ethanol was inhibitory to yeast growth at the concentration used, but did not stop it. This is expected based upon end product inhibition of the yeast which is common in the commercial fermentation of alcoholic beverages (5).

Lactobacillus plantarum grew very well on all tomato juice formulations tested (Table 4). Condiments were only slightly inhibitory and ethanol was moderately inhibitory. Once the population became large enough, inhibition was minimal with growth in 48 hours. In all but the tomato cocktail with 10% ethanol, the death rate was sufficient to give less than 1,000/ml after 16 days. This is indicative of a slower fermentation in the presence of inhibitory substances.

Lactobacillus grew at all inoculum sizes. *Lactobacillus plantarum,* being a homofermenter, did not produce gas as related heterofermentative *Lactobacilli* always do (3). The most notable result of this lactic acid bacterium was the production of acid. All tomato juice formulations tested had a significant increase in the total acidity and a decrease in the pH. *Lactobacilli* also had a markedly fast death rate. The end product acid was the most significant factor in the short death phase (6). Because of this, when a higher pH was used, the *Lactobacillus* remained viable longer. This means that this type of spoilage organism will invade equipment and die out quickly if a new growth medium is not presented.

Leuconostoc mesenteroides grew well only in tomato juice with a higher pH as expected based upon its growth characteristics (5). It did grow briefly with an inoculum of 2,500 cells/ml in tomato concentrate. In the rest of the tomato juice formulations studied, the viability of *Leuconostoc* was quickly reduced. Spices and ethanol were inhibitory *in vivo* as judged from the plate counts.

Bacillus coagulans was also tested. At low levels of contamination, it did not grow below pH 4.3.

Clostridium pasteuranum did not grow in any of the tomato juice preparations tested unless it was heat activated after 16 days. Therefore, it is assumed that low levels of *C. pasteuranum* spores do not pose a threat of spoilage unless they are heat activated.

TABLE 4.—Growth of Lactobacillus plantarum in Various Tomato Juice Formulations (Mean Plate Counts).

Tomato Juice Formulation	Inoculum Size	Days After Inoculation				
		1	2	4	8	10
Tomato juice	1.0×10^4*	4.8×10^5	9.5×10^9	3.2×10^3	3.3×10^3	1.0×10^7
	1.0×10^3	4.8×10^4	9.2×10^6	8.3×10^9	5.5×10^5	1.0×10^8
	1.0×10^2	3.2×10^3	5.1×10^5	8.3×10^9	4.3×10^5	1.0×10^8
Tomato cocktail	1.0×10^4	7.4×10^7	1.1×10^9	7.4×10^5	2.3×10^3	1.0×10^8
	1.0×10^3	4.6×10^4	4.6×10^6	9.8×10^{10}	6.1×10^5	1.0×10^8
	1.0×10^2	3.2×10^3	5.5×10^7	7.6×10^9	5.4×10^5	1.0×10^8
Tomato juice with 10% ethanol	1.0×10^4	2.8×10^6	6.3×10^8	8.6×10^9	4.8×10^7	1.0×10^9
	1.0×10^3	2.9×10^3	3.3×10^3	8.7×10^6	4.5×10^7	1.0×10^8
	1.0×10^2	1.0×10^3	4.7×10^3	8.4×10^4	4.4×10^7	1.0×10^8
Tomato cocktail with 10% ethanol	1.0×10^4	2.4×10^6	1.5×10^8	6.0×10^9	3.9×10^7	9.0×10^6
	1.0×10^3	4.0×10^3	5.3×10^3	7.9×10^6	3.5×10^7	1.9×10^7
	1.0×10^2	1.0×10^3	3.0×10^3	4.3×10^4	5.4×10^6	1.6×10^7
Tomato juice with higher pH	1.0×10^4	8.3×10^8	1.1×10^9	3.4×10^{10}	1.0×10^3	1.0×10^8
	1.0×10^3	4.4×10^3	5.6×10^3	3.7×10^7	2.4×10^8	1.0×10^8
	1.0×10^2	3.8×10^2	3.4×10^4	9.8×10^9	3.7×10^5	1.0×10^8
Tomato concentrate	1.0×10^4	4.8×10^{10}	4.0×10^{10}	2.8×10^7	5.7×10^3	1.0×10^8
	1.0×10^3	5.9×10^4	7.8×10^6	1.4×10^{10}	5.5×10^4	1.0×10^8
	1.0×10^2	3.8×10^3	7.1×10^5	8.2×10^9	2.1×10^5	1.0×10^8

*Organisms/ml.

TABLE 5.—Growth of Leuconostoc mesenteroides in Various Tomato Juice Formulations (Mean Plate Counts).

Tomato Juice Formulation	Inoculum Size	Days After Inoculation			
		1	2	4	8
Tomato juice	2.5×10^{3}*	5.5×10^{5}	3.2×10^{6}	1.0×10^{3}	
	2.5×10^{2}	2.0×10^{4}	4.1×10^{4}	1.0×10^{3}	
	2.5×10^{1}		1.0×10^{3}		
Tomato cocktail	2.5×10^{3}	2.5×10^{5}	0.8×10^{7}	1.0×10^{3}	
	2.5×10^{2}	1.3×10^{4}	9.0×10^{6}	5.9×10^{5}	
	2.5×10^{1}		1.0×10^{3}		
Tomato juice with 10% ethanol	2.5×10^{3}	6.8×10^{4}	2.9×10^{6}	1.0×10^{3}	
	2.5×10^{2}	1.5×10^{3}	3.7×10^{6}	1.0×10^{3}	
	2.5×10^{1}		1.0×10^{3}		
Tomato cocktail with 10% ethanol	2.5×10^{3}	6.2×10^{4}	5.3×10^{6}	1.0×10^{3}	
	2.5×10^{2}	1.2×10^{3}	2.6×10^{6}	1.0×10^{3}	
	2.5×10^{1}		1.0×10^{3}		
Tomato juice with higher pH	2.5×10^{3}	7.5×10^{5}	4.3×10^{9}	1.0×10^{3}	
	2.5×10^{2}	3.4×10^{4}	7.8×10^{8}	1.0×10^{3}	
	2.5×10^{1}		1.0×10^{3}		
Tomato concentrate	2.5×10^{3}	3.5×10^{5}	1.0×10^{8}	7.8×10^{7}	1.0×10^{3}
	2.5×10^{2}	1.9×10^{4}	1.0×10^{3}	1.0×10^{3}	
	2.5×10^{1}				

*Organisms/ml.

Aspergillus sp. and *Geotricum candidum* were also tested. They remained viable after 16 days but were unable to grow anaerobically.

The recommendations for aseptic packaging techniques of all tomato juice formulations are essentially the same. Even with the addition of spices and vodka, yeast and lactic acid bacteria can readily grow. Therefore, a product must either be aseptically processed and packaged or a moderate heat treatment used prior to aseptic packaging. If a moderate treatment is used, the pH should be adjusted enough to exclude sporeformers' growth. The addition of spices and alcohol may allow a reduced heat process. In order for this to be done, "D" values must be calculated for the particular formulation desired.

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Evaluation of Potato Cultivars for Storage and Chipping

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INTRODUCTION

Ohio is a deficit-producing state for potatoes for processing into chips. Potatoes are purchased from Florida to the Dakotas throughout the year to fulfill chippers' needs. In addition to lack of quantity, some cultivars have been found to be not suitable for chipping (1).

This study is a continuation of a long-time study to determine the suitability of Ohio grown potato cultivars for chipping directly from harvest and their storability and chipping after storage. The cultivars included were classified as new cultivars recommended for production.

MATERIALS AND METHODS

The potatoes were grown on six farms strategically located in the respective potato areas in Ohio. These data, including yield data, are included in a separate report (2).

The potatoes, when considered mature by the grower and staff, were machine harvested and a 25 lb sample from each plot was removed directly from the picker chain. These 25 lb samples from each replicate were then delivered to The Ohio State University Food Processing Pilot Plant. Upon receipt at the pilot plant, an 8 lb sample was removed from each lot for specific gravity measurement (PC/SFA hydrometer method) and the number of tubers per 8 lb was recorded. The 25 lb sample from each replicate was sub-sampled, with 3 lb removed for immediate manufacture to chips. The rest of each replicate was blended together with eight sub-lots packaged in bags for storage. Two lots of the eight were placed in 40° F (5° C), two in 45° F (7.5° C), two in 50° F (10° C), and two in 55° F (12.5° C) storage. Following a 3-month storage period, one each of these lots was removed for chipping; the other lot was removed after 6 months' storage and chipped. Upon removal from storage, the lot for each storage period was reconditioned for 1 day, 10 days, and 20 days at room temperature and then manufactured into chips.

The potatoes were manufactured into chips by abrasive peeling for 30 seconds, slicing in a Littrell slicer set for 16-18 slices/inch, and then washing in cold water for 30 seconds. One lb samples were removed from the washed, sliced potatoes. These were fried in a blend of corn and soy oil, using The Ohio State University continuous chip fryer. The inlet temperature was 375° F (190° C), with a discharge temperature of 350° F (176° C) and a fry time between 100 and 110 seconds depending upon the specific gravity of the chips as indicated by the finished moisture content which did not exceed 2.5%.

Following frying, the yield of chips was recorded, the samples were matched to the PC/SFA color chart (light and dark scale) using a MacBeth Examolite to uniformly light the sample for color evaluation. Further, a sample was evaluated with the Agtron E-5F (red filter) at 0 black disk and the white disk (90) at 90. A sample was also evaluated for blisters (½-inch or greater) and defects if any.

RESULTS AND DISCUSSION

The data are presented in summary form for the raw product in Table 1. The color data indicate extremely low reducing sugar content in the tubers at harvest. 'Atlantic' and 'Denali' have very high specific gravity and three cultivars have very low

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TABLE 1.—Raw Product Quality of Potato Cultivars.*

Cultivar	Ct./8 lb	Sp. Gr.	PC/SFA Color (1-5)	Agtron Red (M-30) Color	Percent Blisters
Superior	26.2	1.0718	1.3	55.4	3.5
ND 8891-3	22.6	1.0735	1.5	54.4	14.5
Atlantic	22.2	1.0855	1.6	52.6	10.7
W 718	21.6	1.0703	1.7	53.7	29.5
Norchip	24.6	1.0782	1.5	54.2	19.4
Katahdin	20.4	1.0680	2.1	53.9	15.6
Snowchip	25.0	1.0709	1.7	54.4	4.5
Denali	20.3	1.0861	1.8	54.0	6.3

*Average for six growers.

TABLE 2.—Average Values for Six Growers by Cultivars and Handling Treatments, 1978.

		Agtron Red (M30)												
		Storage	°C:	5		7.5		10		12.5			$\bar{X}$	$\bar{X}$
			°F:	40		45		50		55				
Cultivar	Raw	Days	Mos:	3	6	3	6	3	6	3	6		3	6
Superior	55	1		18	15	26	33	42	48	46	54		33.0	37.5
		10		33	33	34	41	45	52	48	51		40.0	44.3
		20		37	36	36	46	44	51	48	50		41.3	45.8
			$\bar{X}$	29.3	28.0	32.0	40.0	43.7	50.3	47.3	51.7	$\bar{X}$ 40.29		
ND 8891-3	54	1		27	17	35	46	41	55	48	64		37.8	45.5
		10		33	30	42	48	47	58	46	58		42.0	48.5
		20		37	34	44	54	48	57	47	51		44.0	49.0
			$\bar{X}$	32.3	27.0	40.3	49.3	45.3	56.7	47.0	57.7	$\bar{X}$ 44.46		
Atlantic	53	1		28	24	37	52	44	57	47	57		39.0	47.5
		10		44	34	46	55	52	58	49	57		47.8	51.0
		20		46	45	44	61	50	58	50	53		47.5	54.3
			$\bar{X}$	39.3	34.3	42.3	56.0	48.7	57.7	48.7	55.7	$\bar{X}$ 47.83		
W 718	54	1		23	21	32	51	43	62	47	64		36.3	49.5
		10		38	35	40	54	47	58	50	59		43.8	51.5
		20		42	48	46	59	47	61	49	57		46.0	56.3
			$\bar{X}$	34.3	34.7	39.3	54.7	45.7	60.3	48.7	58.7	$\bar{X}$ 47.21		
Norchip	54	1		25	27	34	45	43	59	47	60		37.3	47.8
		10		36	42	40	50	51	58	54	59		45.3	52.3
		20		39	42	46	57	49	60	51	53		46.3	53.0
			$\bar{X}$	33.3	37.0	40.0	50.7	47.7	59.0	50.7	57.3	$\bar{X}$ 46.96		
Katahdin	54	1		23	19	30	35	41	55	47	62		35.3	42.8
		10		31	31	42	44	48	58	52	58		43.3	47.8
		20		44	41	39	51	45	61	46	53		43.5	51.5
			$\bar{X}$	32.7	30.3	37.0	43.3	44.7	58.0	48.3	57.7	$\bar{X}$ 44.00		
Snowchip	54	1		32	28	35	45	43	58	44	59		38.5	47.5
		10		40	48	40	52	49	58	53	58		45.5	54.0
		20		43	53	41	53	48	60	51	55		45.8	55.3
			$\bar{X}$	38.3	43.0	38.7	50.0	46.7	58.7	49.4	57.3	$\bar{X}$ 47.75		
Denali	54	1		27	22	25	50	44	62	44	61		35.0	48.8
		10		39	40	44	53	52	58	53	61		47.0	53.0
		20		42	48	42	57	49	61	50	56		45.8	55.5
			$\bar{X}$	36.0	36.7	37.0	53.3	48.3	60.3	49.0	59.3	$\bar{X}$ 47.50		
			$\bar{X}$	34.46	33.88	38.33	49.67	46.33	57.63	48.63	57.08			

TABLE 3.—Average Values for Six Growers by Cultivars and Handling Treatments, 1978.

		PC/SFA Color (1-5)												
		°C:	5		7.5		10		12.5				$\bar{X}$	$\bar{X}$
		Storage °F:	40		45		50		55					
Cultivar	Raw	Days Mos:	3	6	3	6	3	6	3	6			3	6
Superior	1.3	1	4.9	5.0	4.0	4.5	2.8	3.1	2.5	2.5			3.6	3.8
		10	3.8	4.7	3.5	3.7	2.8	2.8	2.5	2.7			3 2	3.5
		20	3.6	4.3	3.4	3.5	3.0	2.8	2.3	2.8			3.1	3.4
		$\bar{X}$	4.1	4.7	3.6	3.9	2.9	2.9	2.4	2.7	$\bar{X}$	3.40		
ND 8891-3	1.5	1	4.0	5.0	3.6	3.2	2.5	2.5	2.3	1.7			3.1	3.1
		10	3.9	4.6	3.1	3.1	2.4	2.3	2.5	2.0			3.0	3.0
		20	3.4	4.2	2.9	2.7	2.3	2.2	2.3	2.7			2.7	3.0
		$\bar{X}$	3.8	4.6	3.2	3.0	2.4	2.3	2.4	2.2	$\bar{X}$	2.98		
Atlantic	1.6	1	4.0	5.0	3.3	2.7	2.3	2.3	2.3	2.2			3.0	3.1
		10	3.1	4.6	2.6	2.5	2.0	2.0	2.2	2.2			2.5	2.8
		20	2.7	3.2	2.5	1.8	2.2	2.3	2.2	2.5			2.4	2.5
		$\bar{X}$	3.3	4.3	2.8	2.3	2.2	2.2	2.2	2.3	$\bar{X}$	2.70		
W 718	1.7	1	4.4	5.0	3.7	2.7	2.8	1.7	2.4	1.5			3.3	2.7
		10	3.3	4.3	2.9	2.5	2.5	2.2	2.1	2.2			2.7	3.5
		20	3.0	3.2	2.6	2.3	2.6	2.0	1.9	2.0			2.5	2.4
		$\bar{X}$	3.6	4.2	3.1	2.6	2.6	2.0	2.1	1.9	$\bar{X}$	2.74		
Norchip	1.5	1	4.7	4.7	3.8	3.5	2.7	2.1	2.4	1.8			3.4	3.0
		10	3.9	3.7	3.5	3.0	2.0	2.1	1.4	2.0			2.8	2.7
		20	3.6	3.7	3.1	2.5	2.4	2.0	2.0	2.5			2.8	2.7
		$\bar{X}$	4.1	4.0	3.5	3.0	2.4	2.1	1.9	2.1	$\bar{X}$	2.88		
Katahdin	2.1	1	4.4	5.0	4.1	4.3	3.1	2.4	2.6	1.8			3.6	3 4
		10	4.0	4.5	3.1	3.5	2.4	2.2	2.2	2.2			2.9	2.4
		20	3.1	3.7	3.8	3.0	2.8	1.8	3.0	2.5			3.2	2.8
		$\bar{X}$	3.8	4.4	3.7	3 6	2.8	2.1	2.6	2.2	$\bar{X}$	3.15		
Snowchip	1.7	1	4.1	4.8	3.7	3.5	2.8	2.1	2.7	2.2			3.3	3.2
		10	3.1	3.0	2.8	3.0	2.2	2.2	2.1	2.2			2.6	2.6
		20	3.6	2.7	3.6	2.8	2.8	2.0	2.1	2.4			3.0	2.5
		$\bar{X}$	3.6	3.5	3.4	3.1	2.6	2.1	2.3	2.3	$\bar{X}$	2.85		
Denali	1.8	1	4.3	5.0	4.0	2.8	2.7	1.8	2.8	1.8			3.5	2.9
		10	3.4	3.7	2.9	2.8	2.2	2.2	1.8	1.8			2.6	2.6
		20	3.1	3.2	3.5	2.3	2.9	1.8	2.2	2.3			2.9	2.4
		$\bar{X}$	3.6	4.0	3.5	2.6	2.6	1.9	2.3	2.0	$\bar{X}$	2.80		
		$\bar{X}$	3.73	4.20	3.33	3.01	2.55	2.20	2.28	2.19				

TABLE 4.—Average Values for Six Growers by Cultivars and Handling Treatments, 1978.

		Percent Blisters												
		°C:		5		7.5		10		12.5			$\bar{X}$	$\bar{X}$
		Storage	°F:	40		45		50		55				
Cultivar	Raw	Days	Mos:	3	6	3	6	3	6	3	6		3	6
Superior	4	1		9	13	2	7	20	10	7	12		9.5	10.5
		10		12	9	6	2	11	3	10	5		9.8	4.8
		20		10	14	14	15	7	8	6	3		9.3	10.0
			$\bar{X}$	10.3	12.0	7.3	8.0	12.7	7.0	7.7	6.7	$\bar{X}$ 8.96		
ND 8891-3	15	1		15	16	14	22	28	10	17	20		18.5	17.0
		10		10	26	14	13	17	4	17	11		14.5	13.5
		20		25	19	16	16	18	9	7	3		16.5	11.8
			$\bar{X}$	16.7	20.3	14.7	17.0	21.0	7.7	13.7	11.3	$\bar{X}$ 14.63		
Atlantic	11	1		9	27	15	19	37	9	7	15		17.0	17.5
		10		13	19	9	11	9	5	14	12		11.3	11.8
		20		20	16	16	13	8	3	5	0		12.3	8.0
			$\bar{X}$	14.0	20.7	13.3	14.3	18.0	5.7	8.7	9.0	$\bar{X}$ 12.96		
W 718	30	1		28	24	19	26	40	31	20	33		26.8	28.5
		10		25	36	23	34	31	22	31	19		27.5	27.8
		20		23	29	26	18	21	34	19	18		22.3	24.8
			$\bar{X}$	25.3	29.7	22.7	26.0	30.7	29.0	23.3	23.3	$\bar{X}$ 26.25		
Norchip	19	1		20	36	10	16	20	14	13	16		15.8	20.5
		10		23	19	21	15	20	9	22	11		21.5	13.5
		20		12	22	16	17	20	15	13	5		15.3	14.8
			$\bar{X}$	18.3	25.7	15.7	16.0	20.0	12.7	16.0	10.7	$\bar{X}$ 16.85		
Katahdin	16	1		23	13	14	23	21	22	15	29		18.3	21.8
		10		15	20	30	18	21	14	16	12		20.5	16.0
		20		9	22	17	16	13	9	8	2		11.8	12.3
			$\bar{X}$	15.7	18.3	20.3	19.0	18.3	15.0	13.0	14.3	$\bar{X}$ 16.75		
Snowchip	5	1		10	11	7	9	5	8	2	9		6.0	9.3
		10		5	3	20	6	10	4	6	7		10.3	5.0
		20		5	7	9	6	6	6	5	3		6.3	5.5
			$\bar{X}$	6.7	7.0	12.0	7.0	7.0	6.0	4.3	6.3	$\bar{X}$ 7.04		
Denali	6	1		10	11	4	13	5	4	2	9		5.3	9.3
		10		10	13	13	4	15	4	6	5		11.0	6.5
		20		10	10	13	1	4	2	4	2		7.8	3.8
			$\bar{X}$	10.0	11.3	10.0	6.0	8.0	3.3	4.0	5.3	$\bar{X}$ 7.24		
			$\bar{X}$	14.63	18.13	14.50	14.17	16.96	10.79	11.33	10.88			
				16.38		14.33		13.88		11.10			14.36	13.50

blisters ('Superior,' 'Snowchip,' and 'Denali'). The 'W 718' is an extremely high blistering tuber and would not be considered acceptable for chip purposes.

The data in Tables 2 and 3 summarize the color by the Agtron and the PC/SFA color values for the tubers after each of the storages for the two given periods, 3 and 6 months. A good tuber, following storage, should have a color similar to the raw product color. As noted in Tables 2 and 3, the objective and subjective colors for most of the cultivars indicate that they reconditioned quite well. This is believed due to the fact that the sucrose content was extremely low at harvest. It is interesting to note that the long-term storage tubers had better color for the tubers stored at the same temperature than the short-term stored tubers. Again, this would be indicative of low sucrose content for the tubers going into storage.

In 1978 all cultivars could be reconditioned even at 40° F (5° C) to acceptable chips if reconditioned for up to 20 days. The 'Denali' and 'Snowchip' cultivars reconditioned extremely well at the low temperature storage of 40° F (5° C) for 10 days and, at the 45° F (7.5° C) storage, both of these were acceptable 1 day out of storage for long-term storage.

The blister data in Table 4 follow a pattern similar to that shown in Table 1 for the raw product. There are slight differences in terms of low temperature effects for short-term and long-term storage conditions on blisters. It is interesting to note that at the colder temperatures the tubers tended to blister slightly more than at the higher temperatures. Further, at the longer storage, the blistering values were slightly lower than at the short term storage.

Of the new cultivars, the 'Atlantic' and 'Denali' were most impressive, with 'Snowchip' being an excellent tuber from the standpoint of reconditioning and low in percent blisters. These three cultivars are most worthy of continued effort. 'W 718' should not be considered for the chip market.

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Relationship of Sucrose Content in Raw Potatoes to Color of Chips from Stored Potatoes

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INTRODUCTION

The potato tuber is a living plant and should be treated as a perishable commodity after harvesting. U.S.D.A. (6) reported that production of potatoes in the United States for 1978 was 360 million cwt. It has been estimated that 75 percent of this potato crop was placed in storage for later use as table stock or further processed into other food items (1).

The role of stored potatoes is particularly important in the case of the potato chip processor. Potato chip manufacturers process chips throughout the year in order to assure the highest quality products. Most chippers depend upon stored potatoes for approximately 30 weeks out of the year. Generally this period is from early October to mid-April and thus accounts for more than 50 percent of potatoes utilized for chipping coming from storage (1).

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The accumulation of reducing sugars in stored potatoes has been correlated with chip color (2). Sowokinos (4) found that some mature tubers with high sucrose contents may be the major factor in explaining why these cultivars are well known for their inability to produce acceptably colored chips. It was also postulated that the availability and level of sucrose at harvest may be the "critical factor" in determining the initial rate of reducing sugar accumulation and thus their value for processing directly from storage.

Sowokinos (5) addressed this problem by adopting a method for sucrose determination, developed by VanHandel (7), to potato tubers. Potatoes were tested with this method and it was found that tubers which possessed low sucrose levels prior to harvest demonstrated the ability to produce acceptable chips after long-term storage (5).

The purpose of this study is to determine the relationship between sucrose content in potatoes at har-

vest with chip color after storage at constant temperatures (5° C, 7.5° C, 10° C, and 12.5° C) and 1-day reconditioning.

MATERIALS AND METHODS

Eight cultivars were harvested from six Ohio growers. The cultivars used were 'Superior', 'Atlantic', 'Norchip', 'Katahdin', 'Snowchip', 'Denali', and two experimental selections, ND 8891-3 and W 718. Immediately following harvest, the potatoes were transported to the Horticulture Food Processing pilot plant at Howlett Hall on The Ohio State University campus.

Upon arrival, the potatoes were peeled, sliced, washed, and fried in vegetable oil at 191° C for approximately 110 seconds. Samples were evaluated for color both subjectively and objectively using the PC/SFA color chart and the Agtron Red (M-30-A) color difference meter, respectively. This procedure was repeated following 3 and 6 months storage at the four temperature treatments after 1-day reconditioning.

Also upon arrival, samples were removed from the potatoes and frozen at — 27° C. Sucrose analyses were determined after all potatoes were harvested, initially evaluated for color, and stored.

The method for sucrose determination was a modification of the Sowokinos method (5) as follows. A number of potatoes (three to seven depending on size and supply) were peeled, washed, and diced into small pieces. Then 200 grams were weighed and placed in a Waring Blendor along with 250 grams of distilled water. Samples were homogenized for 90 seconds and allowed to separate for 5 minutes before a liquid sample was removed and stored at — 27° C.

Samples were later thawed and filtered through Whatman No. 1 filter paper. Five ml of filtrate were diluted with 20 mil of distilled water. From this, 0.1 ml was placed into cuvettes and readied for analysis. Then 0.1 ml of 30% KOH was added to each cuvette and placed in a water bath at 100° C for 15 minutes. Samples were cooled and 3 ml of anthrone reagent was added to each cuvette. Samples were then mixed and placed into a 40° C water bath for 45 minutes. Following this, the samples were read along with appropriate standards for color on a spectrophotometer at 620 nm. All analyses were carried out in triplicate for each variety and replicate.

RESULTS AND DISCUSSION

The data have not been statistically analyzed yet, but the following trends have been observed. The average sucrose levels for each cultivar from six growers (Table 1) indicate levels below the 2.8 mg sucrose/g tuber that Sowokinos (5) uses as a cut-off for "good processing potatoes."

The average sucrose levels for each cultivar are approximately the same with the exception of the 'Norchip' cultivar. This is also fairly true for the ranges of sucrose levels for cultivars (Table 1).

At harvest, all cultivars produced acceptable colored chips (Table 2). After 3 months' storage and 1 day of reconditioning, the average color for temperatures 5° and 7.5° C was below the minimum value for acceptable chip color (Agtron R value of below 40). The storage temperatures of 10° and 12.5° C produced chips with Agtron color above the minimum acceptable value.

Following 6 months' storage and 1 day of reconditioning, average Agtron color values for six farms were reported. Again, storage temperatures of 10° and 12.5° C resulted in acceptable chip color, while the 5° C storage produced unacceptable chips. At the 7.5° C storage temperatures, six of the cultivars (ND 8891-3, 'Atlantic', W 718, 'Norchip', 'Snowchip', and 'Denali') fried to an acceptable color. Cultivars 'Superior' and 'Katahdin' failed to produce good colored chips at the 7.5° C storage temperature.

In general, the higher the storage temperature, the better the color of the finished chip for both 3 and 6 months. Comparing the color of chips produced from tubers stored for 3 months and from tubers stored at 6 months, a difference is observed. At 5° C storage, 3-month stored tubers give higher color readings than 6-month stored potatoes. At the other stor-

TABLE 1.—Sucrose Content in mg Sucrose/g Tuber for Grower and Cultivar.

Cultivar	Grower: 1	2	3	4	5	6	$\bar{X}$	Range
Superior	1.65	1.48	1.58	1.37	1.07	1.84	1.50	1.07-1.84
ND 8891-3	1.62	1.92	1.89	1.33	0.91	1.56	1.54	0.91-1.92
Atlantic	1.29	2.07	1.88	1.19	1.38	1.07	1.48	1.07-2.07
W 718	1.80	0.97	2.13	1.22	1.38	1.00	1.42	0.97-2.13
Norchip	3.09	2.09	2.64	1.35	1.44	2.29	2.15	1.35-3.09
Katahdin	1.97	1.07	1.89	1.28	1.24	2.06	1.58	1.07-2.06
Snowchip	1.09	1.43	1.75	1.47	1.29	1.09	1.35	1.09-1.75
Denali	1.56	0.62	1.88	1.65	1.74	1.57	1.50	0.62-1.88
Average	1.76	1.46	1.96	1.36	1.31	1.56		-

TABLE 2.—Average Color (Agtron M-30-A) of Chips After 1 Day Reconditioning for Six Growers.

Cultivars	Raw	Storage Time (Mo)	Average Color Value at 5° C	7.5° C	10° C	12.5° C
Superior	55.4	3	18.3	26.3	41.7	45.5
		6	15.3	33.2	47.9	53.8
		$\bar{X}$	16.8	29.8	44.8	49.7
ND 8891-3	54.4	3	27.0	35.0	40.8	48.2
		6	33.4*	46.0	55.1	64.1
		$\bar{X}$	30.2	40.5	48.0	56.2
Atlantic	52.6	3	28.2	37.0	44.3	46.8
		6	23.3*	51.9	57.2	57.1
		$\bar{X}$	25.8	44.5	50.8	52.0
W 718	53.7	3	22.8	33.2	43.3	46.8
		6	20.7	41.2	62.4	63.6
		$\bar{X}$	21.8	36.7	52.9	55.2
Norchip	54.2	3	25.2	34.0	43.2	46.8
		6	27.3	44.8	59.0	60.0*
		$\bar{X}$	26.3	39.4	51.1	53.4
Katahdin	53.9	3	22.8	29.6	41.0	46.8
		6	19.3	34.9†	55.4	61.5
		$\bar{X}$	21.1	32.3	48.2	54.2
Snowchip	54.4	3	31.7	35.0	43.0	44.2
		6	28.1	45.0	58.4	59.3
		$\bar{X}$	29.9	40.0	50.7	51.8
Denali	54.4	3	26.5	25.5	44.0	43.8
		6	22.1	50.4	61.9	61.8
		$\bar{X}$	24.3	38.0	53.0	52.8
Average	54.1	3	25.3	31.8	42.7	46.1
		6	23.7	43.4	57.2	60.2
		$\bar{X}$	24.5	37.7	49.9	53.2

*Average of five growers.
†Average of four growers.

age temperatures (7.5°, 10°, and 12.5° C), the reverse was observed.

The results of this study indicate that low sucrose levels in potato tubers stored at intermediate (10° to 12.5° C) temperature produce acceptably colored chips with storage periods of up to 6 months. Tubers stored at 7.5° C did not meet acceptable color standards after 3 months, but most cultivars (six out of eight) did produce acceptably colored chips after 6 months. The potatoes stored at 5° C never did reach acceptable color levels from either storage period. These trends substantiate those found in previous research on numerous cultivars over an 8-year period (1).

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Reconditioning of Cold-Stored Potato Tubers as Influenced by Harvest Maturity

B. L. HAIR and W. A. GOULD[1]

INTRODUCTION

"Reconditioning" is a term referring to the process whereby excessive reducing sugar concentration in cold-stored potato tubers is lowered to facilitate processing into potato chips. If this were not done, the high reducing sugar concentration would result in formation of brown discoloration during drying and an unacceptable finished product.

Reconditioning is usually accomplished through storage at elevated temperatures (15-20° C) for the length of time necessary to bring about the desired reduction in sugar concentration. Researchers have stated that considerable variation exists among cultivars in their susceptibility to this process (6, 7, 8). Denny and Thornton (1) reported that reconditioning was slower if the tubers had been in cold storage for extended periods, while Yamaguchi, *et al.* (8) indicated that immaturity of the tubers could slow reconditioning.

It has been generally accepted that the processing performance of low temperature stored potato tubers is influenced by their maturity at harvest. Iritani and Weller (3) found that reconditioning significantly reduced the level of sucrose but did not decrease reducing sugar content sufficiently to be of economic significance. Miller (5) said that reconditioning resulted in "slight" improvement of subsequent chip color. On the other hand, Isherwood (4) found that after both sucrose and reducing sugars accumulated during low temperature (2° C) storage, which often led to sugar content of more than 2% on a fresh weight basis, storage at 10° C or greater resulted in a loss of these sugars, "presumably by recondensation to starch." However, he did not process these tubers to determine their suitability.

The objective of this experiment was to determine if tuber maturity at harvest measured by harvest date had significant effects on reconditioning rate or extent when measured by the color of the subsequently produced chips.

MATERIALS AND METHODS

The potato tubers used in this experiment were grown on the Leo Buchholz farm near Wooster, Ohio. Three cultivars widely used in the commercial manufacture of potato chips were chosen. 'Norchip', 'Kennebec', and 'Monona' potatoes were planted on April 7 in three plots. The plots were approximately 25 x 25 meters and were cultured as were those destined for commercial use beside which they were grown.

The tubers were harvested on five different dates and the design of the experiment was completely random within harvest date and cultivar. The harvest dates and sampling dates are given in Table 1. At each harvest, approximately 100 kg of tubers of each cultivar were lifted manually. The three lots of tubers were then transported to the laboratory and stored overnight at 20° C. The three lots were then each divided into 25 samples of approximately 3 kg each. The samples were packaged in unbleached kraft paper bags and randomly assigned a location within the storage unit. The dimensions of the storage unit were approximately 2 meters wide, 3 meters deep, and 2.5 meters high. The temperature was maintained at 5° ± 1° C and the relative humidity at approximately 85% ± 5%. The samples were stored for approximately 7 months.

After storage and 0-4 weeks of reconditioning, the samples were abrasively peeled using a small batch-type abrasive peeler until approximately 80-

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TABLE 1.—Dates of Harvest*, Removal from Storage†, and Processing†.

Harvest Date	Date Out of Storage	Dates of Processing — Weeks of Reconditioning				
		0	1	2	3	4
Aug. 19	Mar. 20	Mar. 20	Mar. 27	Apr. 3	Apr. 10	Apr. 17
Aug. 30	Mar. 28	Mar. 28	Apr. 4	Apr. 11	Apr. 18	Apr. 25
Sept. 6	Apr. 5	Apr. 5	Apr. 12	Apr. 19	Apr. 26	May 3
Sept. 13	Apr. 13	Apr. 13	Apr. 20	Apr. 27	May 4	May 11
Sept. 27	Apr. 28	Apr. 28	May 5	May 12	May 19	May 26

*1977
†1978

90% peel removal was accomplished. The peeled tubers were then sliced manually using a small hand slicer to a thickness of 1.6 mm. The slices were then washed in 30° C tap water and drained on a stainless steel screen to remove excess water.

The slices were fried in fresh soybean oil in a stainless steel fryer equipped with circulating pump, external electric heat exchangers, and an adjustable speed stainless steel submersion belt. The oil temperature was 190° C (375° F) at the inlet where slices were admitted and 177° C (350° F) at the outlet.

The color of chips thus produced was measured objectively using the Agtron M-30-A Reflectance Color Meter with a 16 cm diameter specimen port. The instrument was standardized in the red mode at 0 using the black (00) reference disk and at 90 using the white (90) reference disk (2).

RESULTS AND DISCUSSION

The influence of harvest date and reconditioning time on color of the finished product is shown in Figure 1. Note that the general effect of reconditioning on color was improvement, and this relationship was not apparently affected by harvest date. Note also that all cultivars at all harvest dates attained an acceptable color after some period of reconditioning. The influence of harvest date on the rate at which color improved is illustrated in Table 2. Note that the 'Norchip' and Monona' cultivars exhibited maxima in reconditioning rate at or near the fourth harvest; however, 'Kennebec' exhibited its most rapid rate of reconditioning at the first harvest date.

The data clearly indicate, in contrast to the findings of Iritani and Weller (3) and Miller (5), that color of chips produced from cold-stored tubers can be significantly improved by reconditioning. This improvement would also clearly be of economic significance since chips produced from tubers directly out of storage were totally unacceptable and those produced from reconditioned tubers were at some point quite acceptable (Fig. 1).

The influence of maturity, as measured by harvest date, on reconditioning was not quite as clear.

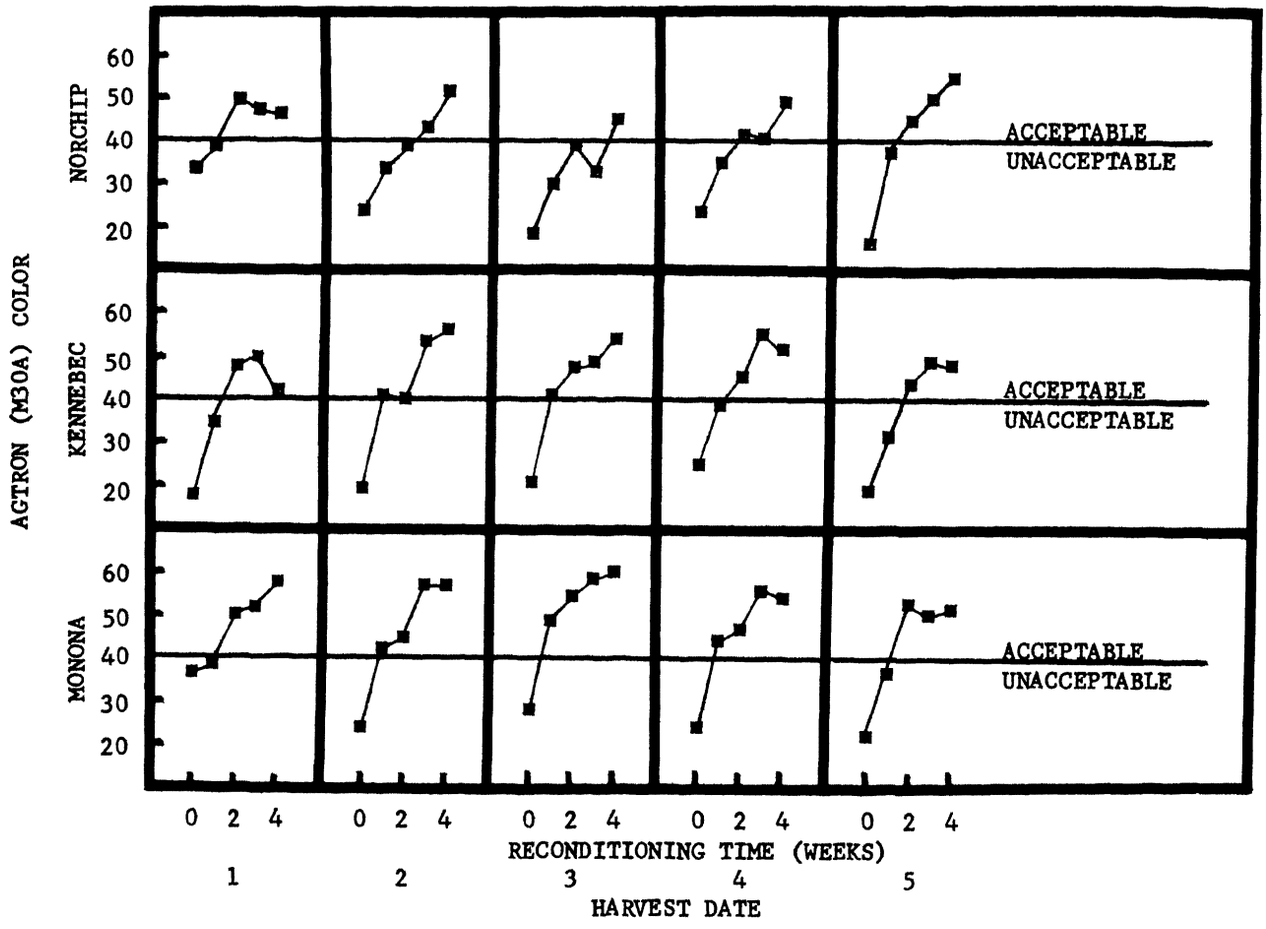

FIG. 1.—The influence of reconditioning time and harvest date on objective color after storage for the various cultivars.

As can be seen from the data in Table 2, the slopes of the reconditioning curves did show significant differences among harvest date by cultivar treatment combinations. In the 'Norchip' and 'Monona' cultivars, rate of reconditioning did appear to increase through harvest number 4 which is in general agreement with observations in the literature (8). However, the behavior of the 'Kennebec' cultivar was apparently not affected by maturity in the same manner, which is once again in agreement with previous researchers' findings of variable cultivar susceptibility to reconditioning (1, 6, 7).

It appears that tubers of 'Norchip', 'Kennebec', and 'Monona' potatoes can be harvested and stored at 5° C for 7 months and reconditioned to an acceptable color after 2 to 4 weeks. Furthermore, it appears that tubers of 'Norchip' and Monona' became more predisposed to rapid reconditioning with advancing maturity.

TABLE 2.—Duncan's Separation of Means for Differences in Rate of Reconditioning with Harvest Date (at 5%).

	Reconditioning Rate		
Harvest Date	Norchip	Kennebec	Monona
1	1.24 ef	2.08 bc	0.99 f
2	1.01 f	1.56 cdef	1.43 def
3	1.57 cdef	1.90 bcd	1.82 bcde
4	1.77 bcde	1.50 cdef	2.71 a
5	1.75 cde	1.73 cde	2.37 ab

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Role of Glucose and Sucrose in Potato Chip Discoloration

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INTRODUCTION

To provide uniform product flow and efficient processing equipment utilization in the production of potato chips, the tubers are generally placed in storage. However, storage at low temperatures has been shown to lead to the accumulation of reducing sugars and sucrose, while higher temperature storage leads to excessive weight losses from dehydration and sprouting unless sprout inhibitors are used.

In 1945, Legault (5) confirmed that the browning of potato chips was, at least in part, due to a Maillard type reaction involving reducing sugars. Habib and Brown (3) showed that chip color as measured by Hunter L was significantly correlated with reducing sugar content of the raw tubers. However, they also found instances where high reducing sugar content did not result in dark color, and vice versa. Earlier work by Sweetman (8) had shown that brown color of potato chips seemed to increase with increase in total sugar content of the tubers. Later Thornton (9) stated that at the temperature of frying only reducing sugar content, and not sucrose, was responsible for the brown color of chips. Wright and Whiteman (10) agreed that reducing sugars greatly affected the color of potato chips. More recent work by Miller (7) agreed that glucose was perhaps the major determinant of chip color.

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MATERIALS AND METHODS

Potatoes were grown, harvested, and stored as described earlier (4). The same methods were used until after storage and 0-4 weeks of reconditioning and the abrasive peel removal. At this point, the peeled tubers were halved longitudinally and half of each tuber was retained for subsequent analysis. One half was treated as described previously (4); the other half tubers were diced and frozen at — 20° C

FIG. 1.—Chromatographic parameters for the separation of trimethylsilyl ethers.

CHROMATOGRAPH (Varian Model 3700, Flame Ionization Detector)
- INITIAL TEMP—140° C, INITIAL TIME—15 MIN
- PROGRAM RATE—2 C/MIN
- FINAL TEMP—226° C, FINAL TIME—5 MIN
- SAMPLE SIZE—1 μl
- RANGE—10^{-10}, ATTENUATION—4
- FLOW RATES—
  - He—20 ml/min (carrier)
  - H_2—30 ml/min
  - Air—300 ml/min
- INJECTOR TEMP—260° C, DETECTOR TEMP—300° C
- CHART—5.1 mm/min

COLUMN
- DIMENSIONS—183 cm X 3.2 mm OD stainless steel
- SUPPORT—Gas Chrom Q (80/100 mesh)
- STATIONARY PHASE—OV-17 (3%)

INTEGRATOR
- BASELINE CORRECTOR—on, RATE—75%
- PEAK DETECTOR—
  - noise adjust—4
  - slope sensitivity—32
  - filtering—4
- RECORDER—
  - event marker—on
  - attenuator—4

and then freeze-dried at 50° C. The resulting dices were ground in a Wiley mill with a 40 mesh screen installed and stored in glass, in the dark, under desiccation for subsequent analyses.

Glucose and sucrose were determined by a modification of the method used by Marsili (6). The freeze-dried powder was extracted with 0.5% trichloracetic acid, a diatomaceous filter aid was added, and the mixture was filtered. After filtration, 0.5 ml of the filtrate was placed in a 10 x 75 mm culture tube, frozen, freeze-dried, and stoppered with aluminum foil. To the dried residue was added 0.25 ml of trimethylsilylimidazole (TSIM) and the mixture was heated at 95° C for 50 minutes. A 1 μl sample was injected into the gas chromatograph with operating parameters set as shown in Figure 1. Peak quantification was accomplished using the external standard method and totalized digital integration. Peaks were identified by retention time, peak reinforcement, and with assistance from the literature (1, 6) (Fig. 2).

RESULTS AND DISCUSSION

The influence of reconditioning time and harvest date on sucrose concentration are illustrated in Figures 3, 4, and 5. Note that the general effect of reconditioning seems to have been a reduction in sucrose concentration to similar low levels regardless of harvest date. Note also the rise in sucrose content, in some cases after 1 week, and again in some cases after 4 weeks of reconditioning.

The general effects of reconditioning on glucose concentration were very similar to those noted for sucrose above. Note also the very large increase in glucose after 1 week of reconditioning in the 'Norchip' tubers harvested at the last three harvest dates, and similar trends in 'Kennebec' and 'Monona'.

The general effect of reconditioning on color was improvement, and this relationship was not apparently affected by harvest date. Note also that all cultivars at all harvest dates attained an acceptable color after some period of reconditioning.

Recalling the very sharp increases in glucose

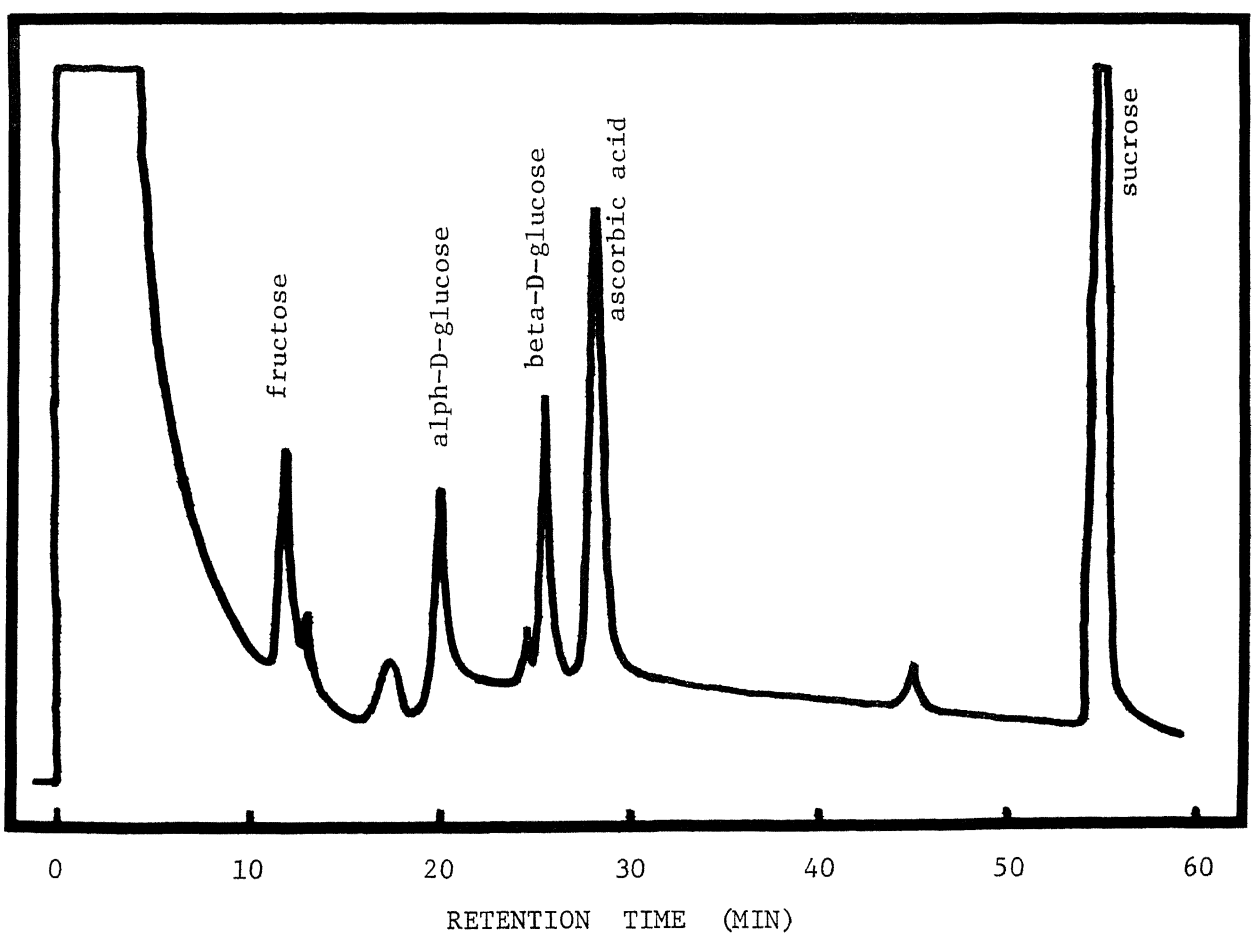

FIG. 2.—A typical chromatogram of the trimethylsilyl ethers of the various sugars and ascorbic acid.

concentration, especially in 'Norchip' tubers after 1 week of reconditioning, if glucose was indeed the major determinant of chip color, one would expect a concurrent sharp decrease in color of the finished product. However, this was clearly not the case. In fact, in almost every case the color of the subsequently processed product showed steady and fairly uniform improvement throughout the reconditioning period.

If the predominant cause of the discoloration of the finished product was a caramelization reaction involving sucrose, the steady improvement of color is still not explained.

It is therefore evident that there are factor(s) other than glucose and sucrose contents which affect the browning reaction resulting in the discoloration of potato chips. In addition, these factor(s) seer be somehow controlled by the reconditioning proc

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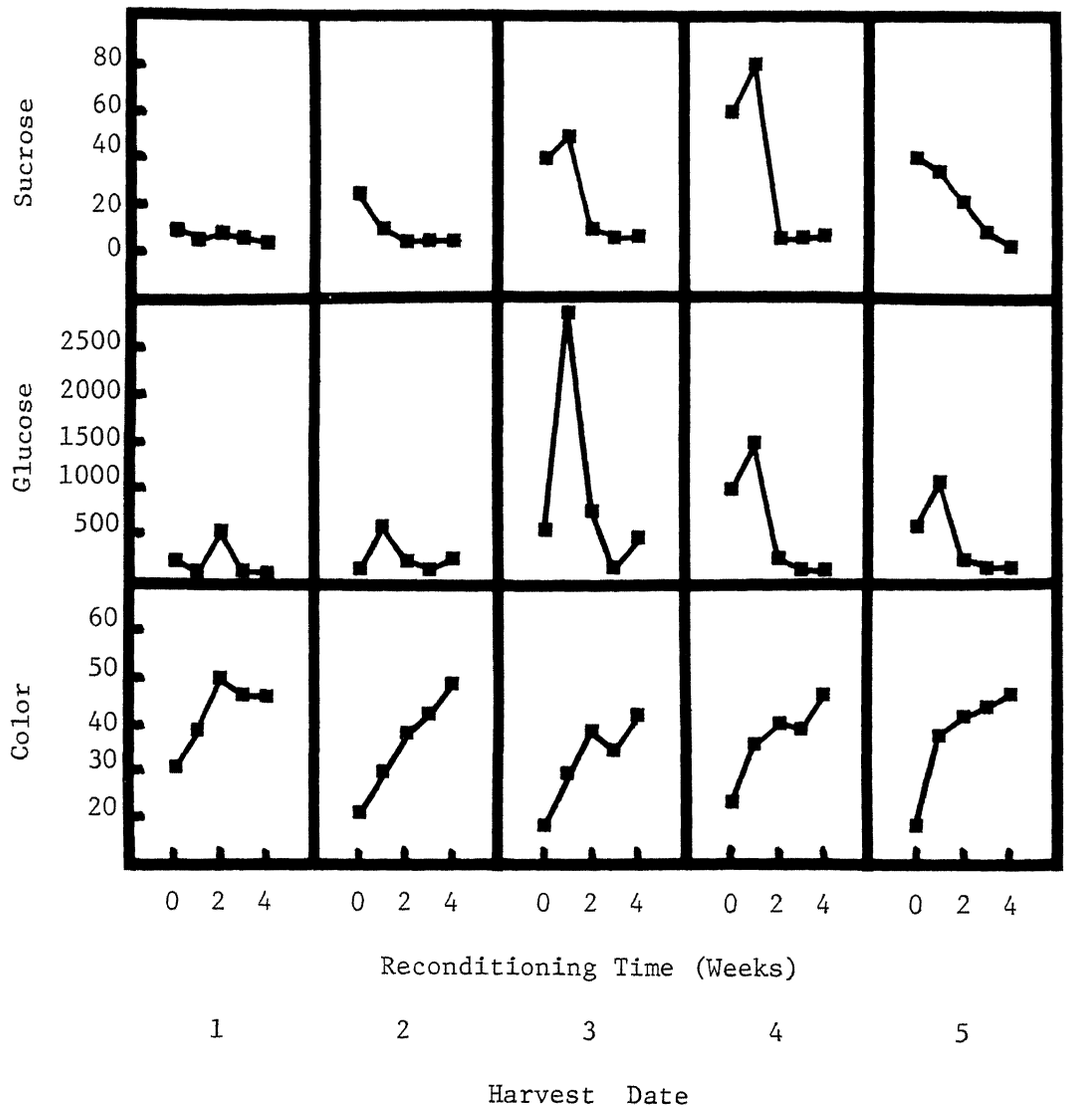

FIG. 3.—Influence of reconditioning time and harvest date on sucrose and glucose content of the tuber and color of the subsequent chips of 'Norchip'.

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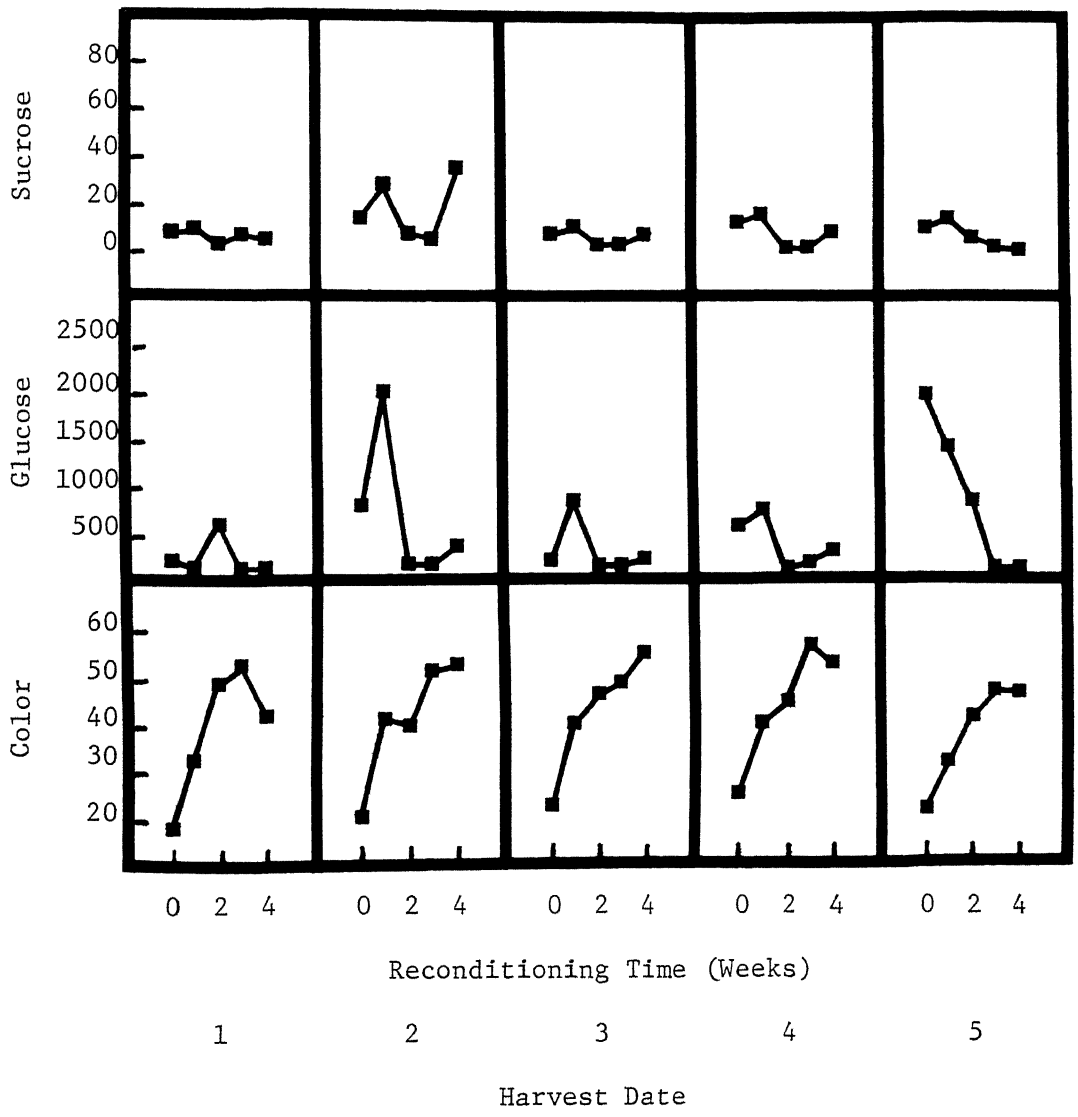

FIG. 4.—Influence of reconditioning time and harvest date on sucrose and glucose content of the tuber and color of the subsequent chips of 'Kennebec'.

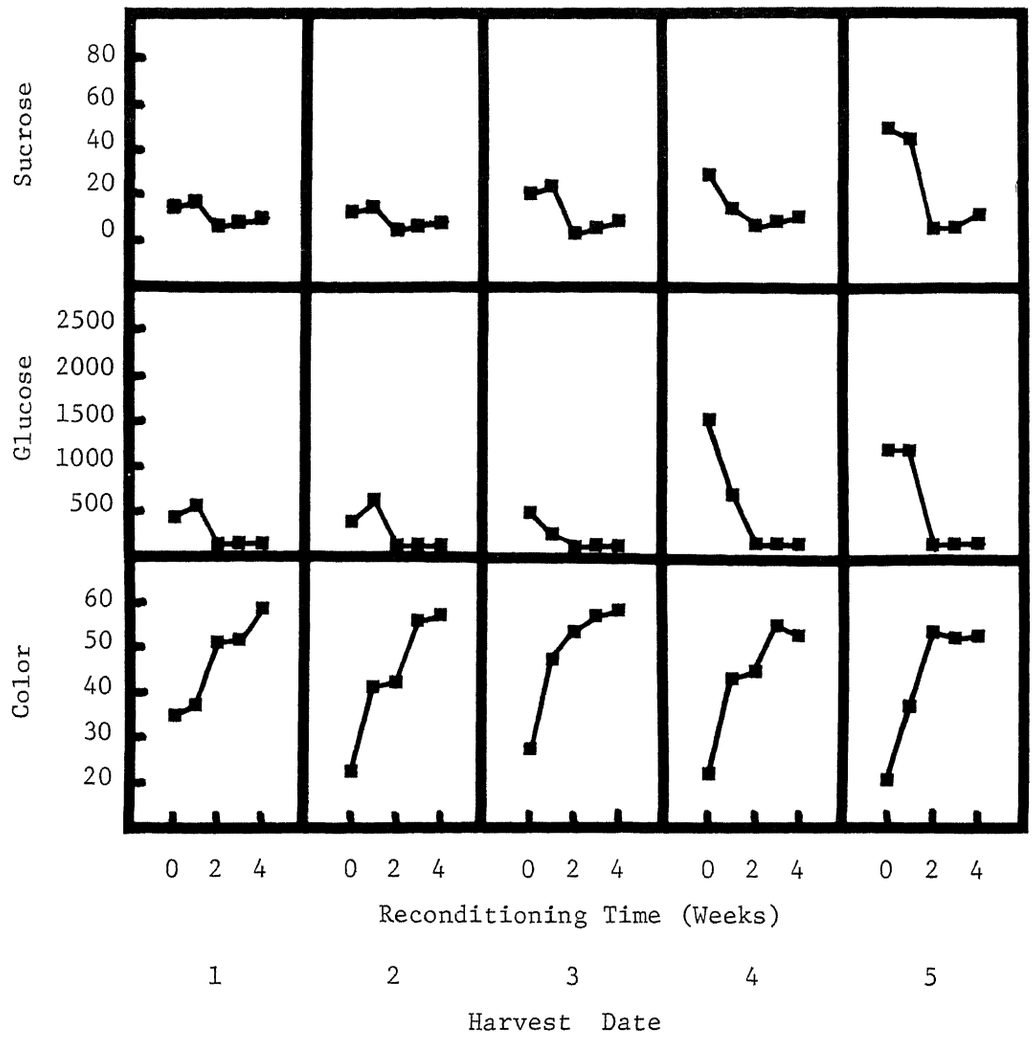

FIG. 5.—Influence of reconditioning time and harvest date on sucrose and glucose content of the tuber and color of the subsequent chips of 'Monona'.

Harvest Sucrose Content as an Indicator of Post-Storage Processing Performance

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INTRODUCTION

It has generally been accepted that the post-storage processing performance of potato tubers is influenced by their maturity at harvest. However, research has not provided a precise definition or an accurate method for determining processing maturity (10). The major factor limiting the utilization of potatoes in chip manufacture is the accumulation of reducing sugars before and during storage (2). However, the precise mechanism whereby this takes place is not fully understood. To further complicate the situation, different cultivars have been found to accumulate sugar at different rates and this is further complicated by storage conditions (1, 7).

Sucrose is known to be the major free sugar found in immature tubers of potato (9). Sowokinos (10) found sucrose content at harvest to be correlated with the $\log_{10}$ of the storage life of that cultivar (or selection) by maturity combination. His data indicated that if a cultivar was able to reduce its sucrose concentration below 2.8 mg/g of tissue, it would prove suitable for processing directly from long-term intermediate temperature (12° C) storage.

According to Isherwood (6), low storage temperatures (2-7° C) resulted in elevation of the sucrose content to levels above those at harvest due to cold induced starch degradation. Hence, it could be assumed that all cultivars would be rendered unsuitable for processing due to this sucrose accumulation that would be followed by invertase production of excessive reducing sugar. However, O'Keefe (8), through data on more than 50 cultivars (or selections), 10 locations, and multiple seasons, found that tubers with low sucrose are generally better able to survive cold storage or cold storage and reconditioning than those with higher sucrose content. Iritani and Weller (5) arrived at similar conclusions. Miller *et al* (7) also noted significant declines in sucrose content with maturity; however, color of chips from tubers harvested after sucrose had declined to a fairly constant low was the darkest encountered in the experiment.

The objective of this experiment was to observe changes in tuber sucrose content with advancing maturity and determine if any changes observed are re-

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TABLE 1.—Correlation Coefficients for Color (PC/SFA and Agtron) vs. Reconditioning Time (Recond) and Harvest Sucrose Content (Sucl) by Cultivar and Harvest Date.

Harvest Date	Correlation Coefficients			
	PC/SFA		Agtron	
	Recond	Sucl	Recond	Sucl
		Norchip		
1	— 0.91	— 0.41	0.78	0.41
2	— 0.98	— 0.19	0.99	0.30
3	— 0.99	— 0.46	0.90	0.26
4	— 0.92	— 0.74	0.95	0.58
5	— 0.90	0.45	0.93	— 0.40
		Kennebec		
1	— 0.58	0.93	0.77	— 0.81
2	— 0.96	0.76	0.94	— 0.73
3	— 0.96	— 0.22	0.91	0.30
4	— 0.91	— 0.40	0.92	— 0.47
5	— 0.93	0.45	0.92	— 0.44
		Monona		
1	— 0.97	0.15	0.95	— 0.10
2	— 0.97	— 0.40	0.93	0.33
3	— 0.94	0.33	0.90	— 0.17
4	— 0.93	0.51	0.91	— 0.59
5	— 0.89	— 0.03	0.85	0.14

flected in the post-storage processing performance of these tubers.

MATERIALS AND METHODS

Potatoes were grown, harvested, and stored as described in two other articles by the same authors (3, 4).

RESULTS AND DISCUSSION

Harvest sucrose concentration was found to vary significantly with both harvest date and cultivar. Tubers from the first and fourth harvests were shown to have the highest concentrations of sucrose (Fig. 1). Note also that a sucrose concentration of 20 μM/g of tissue is equivalent to almost 7 mg/g and well above the 2.8 mg/g that the literature indicates is the maximum acceptable for tubers intended for long-term storage (10). The 'Monona' cultivar was found to have the highest concentration of sucrose.

Correlation analyses of the harvest sucrose content vs. initial color after storage, final color after storage and 4 weeks' reconditioning, and rate of reconditioning was performed. Sucrose content at harvest was found to be highly correlated with only initial color after storage; however, the correlation coefficient was only 0.525.

Correlation analyses were performed for color vs. reconditioning time and harvest sucrose content by cultivar and harvest date (Table 1). As shown by the data, color after storage was consistently and highly correlated with reconditioning time, but not with initial sucrose content.

The results of correlation analyses between sucrose content at harvest and intial color after storage, final color after storage and 4 weeks' reconditioning, and rate of reconditioning yielded only one rather weak significant correlation. These results seem to sum up the usefulness of sucrose as a general indicator of potato tuber maturity and processing maturity. Since it was not correlated well with color after storage and not at all with the other attributes, it does not appear to be a very good predictor of post-storage processing performance. Furthermore, reconditioning time proved a much more successful and consistent predictor of post-storage color than sucrose concentration at harvest.

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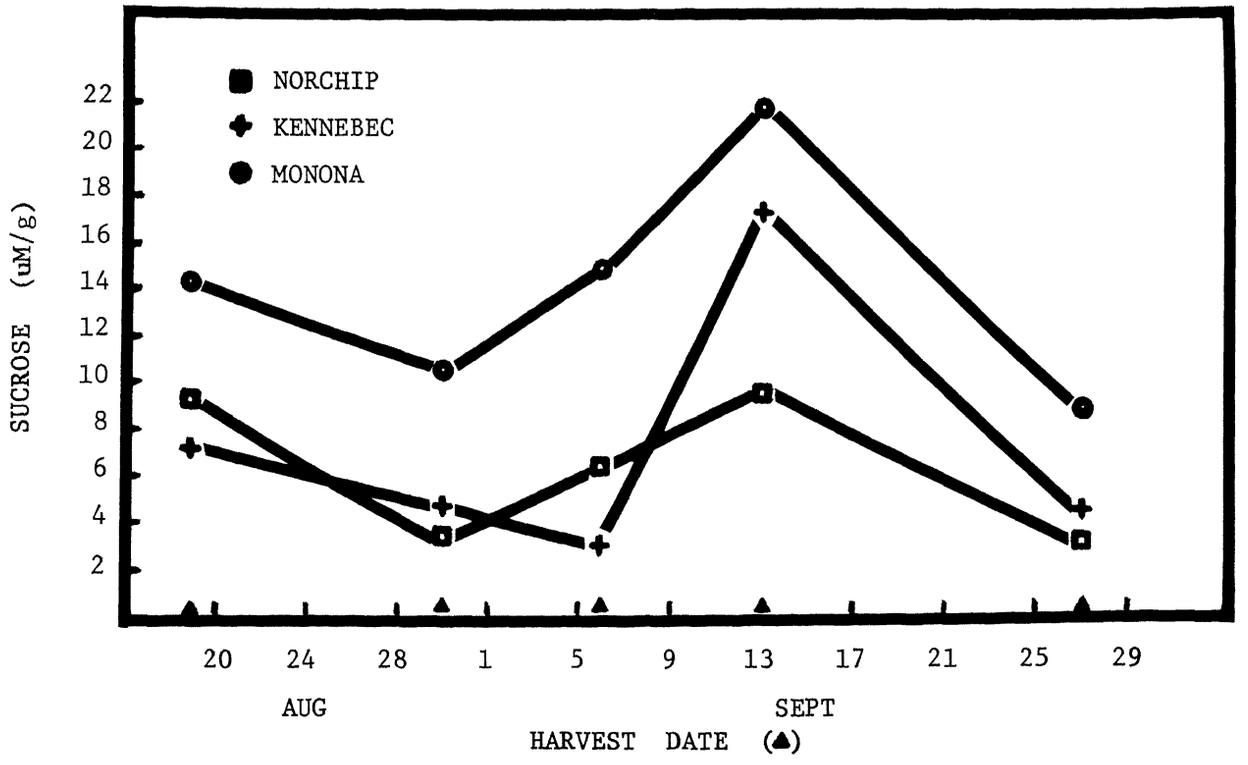

FIG. 1.—Changes in sucrose concentration with advancing maturity for the various cultivars.

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Lipid Changes Occurring in Cabbage During Storage

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INTRODUCTION

Cabbage (*Brassica oleracea* var. *Capitata,* L.), one of the cruciferous vegetables, is low in calories. The main component that contributes to such low energy value is primarily the lipid content. The predominant fatty acids in cabbage lipids are linolenic (18:3), linoleic (18:2), oleic (18:0), palmitic (16:0), and stearic (18:0) acids (6). The first two are essential for the human body.

Leafy vegetables are perishable. Storage is the only means to extend the supply the year around. After harvest, to meet the needs, cabbage is usually stored before it reaches the consumer's table.

Cabbage lipid content is relatively low, usually 0.16% (6). Due to the highly unsaturated nature of its fatty acids, this small quantity of lipids is responsible for storage stability. Changes in lipid composition during storage have been studied in sweet potatoes (1, 2) and potato tubers (9). Salunkhe *et al.* (8) have assessed the nutritive value, quality, and stability of cruciferous vegetables during storage.

The objectives of this study were to investigate the changes occurring in total lipids when cabbage was stored at two different temperatures, and to analyze the alteration in fatty acid composition.

MATERIALS AND METHODS

Preparation of Sample

King Cole cabbage was obtained from The Ohio State University horticultural farm, Columbus, Ohio, and stored at 1° C and 7° C. A certain portion of the sample was removed at 0, 2, and 3-month intervals from the 7° C cooler and 0, 2, 3, and 4-month intervals from the 1° C cooler. The outer leaves were removed and the head was cleaned. The cleaned head was cut into quarters, and shredded with a kraut cutter.

The cut cabbage was thoroughly mixed in order to have an even distribution of lipids. Samples (200 g) were placed in plastic bags and frozen for future analysis. Moisture was determined by weight difference by drying in a recirculating oven at 100 ± 5° C for 20 hr.

Lipid Extraction

Duplicate frozen samples (200 g) were blended with 200 ml distilled water in a Waring Blendor for 3 min. The slurry was mixed thoroughly with 20 g silicic acid and 10 g Celite. The mixture was filtered through Whatman No. 1 paper in a Buchner funnel under reduced pressure.

The sample pad was extracted in a Waring Blendor with 200 ml Folch agent (3) consisting of chloroform-methanol (2:1, v/v) for 3 min at room temperature and filtered as previously described. The residue was re-extracted with another portion of 200 ml solvent, filtered, washed twice with 25 ml solvent/washing, and 25 ml chloroform.

The extracts and washings were pooled, quantitatively transferred to a separatory funnel, and allowed to stand for 5-10 min. The lipid phase was collected; the upper aqueous phase was washed with 30 ml chloroform and this was added to the lipid

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TABLE 1.—Lipid and Moisture Changes After Storage (%).

Time (Month)	7° C		1° C	
	Lipid	Moisture	Lipid	Moisture
0	0.10	93.72	0.10	93.72
2	0.05	94.64	0.08	93.80
3	0.08	94.65	0 07	93.07
4			0.06	93.85

phase. The extract was left in a refrigerator overnight for complete separation. The solvent was then removed by a rotary evaporator at reduced pressure at 40° C. The sample was stored in a vacuum desiccator until a constant weight was obtained.

Gas-Liquid Chromatographic (GLC) Analysis

Qualitative and quantitative determinations of fatty acids were carried out as previously reported (6, 7) by using a Packard Model 409 Becker Gas Chromatograph (Packard Instrument, Downers Grove, Ill.) equipped with a flame ionization detector, Bristol Dynamaster recorder, and disc chart integrator. Methyl esters were prepared according to Metcalfe *et al.* (5) with boron-trifluoride methanol. A coiled stainless steel column (8 ft x 1/8 in OD) was packed by Applied Science Labs., State College, Pa., with 15% by weight diethyleneglycol succinate (DEGS) and 1% by weight phosphoric acid on acid-washed Chromosorb W, 80-100 mesh as the support phase. Identification was made by comparing the retention time with reference methyl ester derivatives and by plotting retention time vs. carbon number on semilog paper. The fatty acids were expressed as area percentage of the total peak area. Unsaturation was verified by bromination (4).

RESULTS AND DISCUSSION

Total Lipid Content

After cabbage is harvested it is still physiologically active, with enzymatic and respiratory processes continuing. The higher storage temperature induces greater physiological activities, requiring more energy as shown in Table 1. Total lipids decreased more rapidly at 7° than those stored at 1° C. In other words, lower storage temperatures would reduce such activities. The color of the outer leaves was still green after 3 months at 1° C, while the outer leaves of those heads stored at 7° C were already yellow and dehydrated. Moisture content was nearly constant at 1° C and slightly increased at 7° C, which was probably due to the higher respiration rate.

Fatty Acid Composition

The quantitative changes of fatty acids in total lipids are listed in Table 2. There were 40 peaks observed on the gas-liquid chromatogram, but only those containing 1% or more were reported. The types of fatty acids were typical of plant lipids, al-

TABLE 2.—Fatty Acid Composition of Total Lipids After Storage (%).*

Fatty Acid†	7° C Storage			1° C Storage			
	0 Month	2 Months	3 Months	0 Month	2 Months	3 Months	4 Months
8 0		1.0	1.2		1.9	1.5	1.7
9.0	2.3	0.5	0.8	2.3	1.1	1.7	2.3
10:0	1.5	0.3	0.5	1.5	0.5	1.2	1.5
11:0	1.3	0.2	0.8	1.3	0.4	1.2	0.9
14·0	1.8	1.8	1.8	1.8	1.6	1.8	2.1
15·0	2.5	3.4	2.8	2.5	2.9	3.1	3 3
15:1	1.5	1.4	1.5	1.5	0.6	1.0	1.2
16·0	20.8	16.6	21.3	20.8	26.0	23.7	26.8
16:1	4.5	3.4	1.3	4.5	2.4	4.1	4.0
17:0	0.9	1.9	1.0	0.9	1.4	1.1	1.2
17:1	12.4	11.9	6.4	12.4	10.4	12.4	13.4
18:0	6.2	6.7	4.9	6.2	4.2	5.6	7.1
18·1	3.4	13.0	13.8	3.4	5.7	7.8	8.9
18:2	0.9	1.9	3.3	0.9	2.3	1.6	1.3
18:3	1.1	6.5	9.7	1.1	4.5	2.2	2.2
21:0	1.8	2.0	1.9	1.8	2.6	1.6	0.4
21:1	2.5	1.5	2.1	2.5	3.4		
22:0	4.2	1.4	2.0	4.2	5.3	2.3	2.4
22:1	7.1	1.5	2.6	7.1	5.1	2.5	2.3
23:1	5.2	9.8	2.8	5.2	3.4	3.0	
24:0	5.9	2.9	3.8	5.9	5.6	5.4	5.2
24:1	8.9	1.7	2.8	8.9	5.2	3.9	2.5

*Only 1.0 % or more reported.
†Carbon number:number of double bond.

though considerable differences were observed in their quantitative distribution at different storage temperatures and sampling dates. Total unsaturated fatty acids appeared to change more than the saturated acids during storage, and the rate of change was higher at 7° C storage than the 1° C storage. There was no definite pattern, since some acids increased with time and some gave the opposite result.

The distribution of major fatty acids in this study disagreed with that of previous findings (6) for the cultivar Golden Acre Yellows Resistant, whose acids were 18:3 > 18:2 > 18:1 > 16:0 > 18:0 > 17:1 in decreasing order as compared to King Cole, 16:0 > 17:1 > 18:0 > 18:1 > 18:3 > 18.2. This discrepancy proved that different cultivars have different fatty acid compositions. The high level of lignoceric (24:0) and nervonic (24:1) acids may be an artifact which arose during storage.

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The Effect of Coagulants on Protein Content and Amino Acid Composition of Soybean-Cheese Whey Curd

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INTRODUCTION

Soybean curd, also known as dow foo or tofu, has been an important and popular food in the Orient for centuries. It is high in lysine and moderately low in methionine. This deficiency may be nutritionally improved by complementation with cheese whey which is high in all essential amino acids and especially the sulfur-containing amino acids (9).

Numerous investigations have been conducted on the effect of coagulants such as magnesium chloride, calcium sulfate, calcium chloride, ferric chloride, and others on the texture and yield of soybean curd (5, 7, 10). No literature is available reporting the effects of different coagulants on the composition of soybean-cheese whey curd.

It is the authors' experience that the traditional method of making soybean curd with calcium sulfate failed to completely coagulate a soybean-cheese whey mixture into curd. The function of calcium sulfate is to increase ionic strength and not to reduce pH to the isoelectric point.

The objectives of this study were to investigate the proper coagulants for making a soybean-cheese whey curd; to evaluate the aroma, texture, yield, moisture, and protein contents of the curd; and to determine the amino acid composition.

MATERIALS AND METHODS

Preparation of Soybean-Cheese Whey Milk

Soybeans (*Glycine max*) were cleaned and soaked in four volumes of cold tap water for 12 hours at 0° C. The soaking water was decanted and the beans were rinsed. The beans were added to cold tap water and finely ground in a Waring Blendor for 3 minutes. The bean slurry was filtered through four layers of cheesecloth. The final meal-water ratio was 1:10 (w/w). The aqueous extract is known as soybean milk. The milk was boiled for at least 15 minutes to destroy any trypsin inhibitor present.

A sodium cheese whey protein concentrate (1) was thoroughly dispersed in hot water at a ratio of 1:10 (w/v). Then soybean milk and cheese whey milk were mixed in different ratios.

Determination of Proper Coagulants

Several organic and inorganic compounds, such as calcium chloride, calcium sulfate, magnesium chloride, magnesium sulfate, potassium acetate, potassium tripolyphosphate, hydrochloric acid, ascorbic acid, lactic acid, tartaric acid, acetic acid, carrageenan, carboxymethyl cellulose, glucono-delta-lactone, and certain combinations were screened as coagulants. The criteria for selection were yield, texture, and aroma of the curd. Glucono-delta-lactone, calcium sulfate, and magnesium chloride met these requirements and were further evaluated in this experiment.

Preparation of Soybean-Cheese Whey Curd

Three different coagulants were added: (a) glucono-delta-lactone, 0.6% (w/v); (b) glucono-delta-lactone, 0.6%, and calcium sulfate, 0.05%; and (c) glucono-delta-lactone, 0.6%, and magnesium chloride, 0.17%. After the curd was formed and stood for 30 minutes, the serum was separated by straining through two layers of cheesecloth in a plastic box with holes on each side and the bottom. The cheesecloth lining the box was then folded and a pressure (0.036 psi) was placed on the top for 15 minutes. The curd was then removed from the box and analyzed.

A soybean curd was made with 0.25% of calcium sulfate and used as reference.

Evaluation of Aroma

The sensory evaluation was performed by a taste panel from which the aroma of samples was classified into three categories: beany, bland, and raw milk.

Evaluation of Texture

The textural properties of the curds were measured with the aid of a Precision Universal Senior Model Penetrometer (Precision Scientific Co., Chicago, Ill.). The total weight to penetrate the samples was 90.8 grams. Readings for the textural measurements were expressed as the depth (mm) of penetration for 5 seconds.

Measurement of Moisture Content

All samples were dried at 75° C for 48 hours in a recirculating oven. The moisture content of the curds was determined by weight difference before and after drying.

Calculation of Yield

The yield was calculated on a dry weight basis.

$$\text{Yield (\%)} = \frac{\text{fresh sample wt} \times (100 - \text{\% moisture content})}{\text{raw material wt}}$$

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Determination of Protein Content

Micro-Kjeldahl (3) was used to determine the protein content. Crude protein was calculated by the factor 6.25 and expressed as percentage of the dry sample weight.

Analysis of Amino Acid Composition

The amino acid composition of the curds was analyzed using a Technicon auto analyzer in the Department of Agronomy. Computations were made by the Statistics Laboratory, OARDC.

RESULTS AND DISCUSSION

Proper Coagulant and pH Value

Glucono-delta-lactone (GDL) is an inner ester of gluconic acid. When it hydrolyzes, it produces a mixture of gluconic acid and its delta and gamma-lactones (2). Therefore, a solution of GDL exhibits a low pH. The isoelectric point of cheese whey is about pH 5.3 (4) and of soybean protein is at pH 4.2 (8). Thus, the isoelectric point of a mixture of equal amounts of soybean and cheese whey is expected to be around pH 4.75. But the pH value of the mixture by GDL precipitation was around pH 5.0, while plain soybean curd was pH 4.6 and plain cheese whey curd pH 5.15 (Table 1). This variation of pH may be due to varying buffering capacities of different protein components, since proteins are ampholytes which act as both acids and bases (11).

Several organic and inorganic acids were used to precipitate the proteins, but their products had a sour aroma. The amount of acid required to obtain a desired texture varied with the type and concentration of the acid.

The traditional method of preparing the curd is to use salts, such as calcium sulfate, magnesium chloride, and other salts containing divalent ions. The protein is completely precipitated when the concentration of neutral salts is quite high; this effect is called salting-out (4, 11). The salting-out effect does not reduce the pH value to its isoelectric point as is proved by the result that the soybean curd precipitated by calcium sulfate was at a pH of 6.1.

Most salts containing divalent ions could precipitate soybean and cheese whey proteins. However, the results showed that calcium sulfate was only a good coagulant for making soybean curd and did not precipitate soybean-cheese whey protein mixture. This was probably due to the low solubility of calcium sulfate itself in the milk mixture. A saturated solution of calcium sulfate may have been obtained before the concentration of calcium ions in the milk reached the salting-out level.

Aroma and Texture

Results indicated that the curd made from 50% soybean and 50% cheese whey was bland without a beany or raw milk aroma. Since most Westerners are not accustomed to the beany flavor, the curd with a bland or raw milk aroma would be most acceptable.

The texture data (Table 2) showed that the curd mixture was softer than the two plain curds. This might be correlated to the moisture content of the curd. Data in Table 3 revealed that the moisture content of the soybean-cheese whey curd was higher than either plain curd. The higher the moisture content, the softer was the curd texture.

The curd made with GDL was softer than any combined coagulants. This may be due to the gelling property of GDL which made the mixture a gell-type product. It could be speculated that an interaction between GDL and whey protein and/or soybean protein may be taking place, because GDL was the only chemical added to the mixture. GDL also

TABLE 1.—The pH Value of Soybean-Cheese Whey Milk Mixture Before and After Treatment.

Treatment	Percent Soybean / Percent Cheese Whey	100 / 0	60 / 40	55 / 45	50 / 50	45 / 55	40 / 60	0 / 100
No Treatment		6.6	6.5	6.5	6.5	6.45	6.45	6.35
$CaSO_4$		6.1						
G. D. L.		4.6	5.05	5.05	5.1	5.1	5.1	5.15
G. D. L. + $CaSO_4$		4.75	5.05	5.1	5.1	5.15	5.15	5.35
G. D. L. + $MgCl_2$		4.5	4.85	4.9	4.9	5.0	5.0	5.1

TABLE 2.—Texture of Soybean-Cheese Whey Curd (mm/5 sec*).

Treatment	Percent Soybean / Percent Cheese Whey	100 / 0	60 / 40	55 / 45	50 / 50	45 / 55	40 / 60	0 / 100
$CaSO_4$		1.4						
G. D. L.		2.1	3.8	3.75	3.85	3.60	3.95	2.6
G. D. L. + $CaSO_4$		1.05	3.70	3.75	3.65	3.50	3.55	2.65
G. D. L. + $MgCl_2$		0.90	1.80	1.70	1.95	1.65	2.10	1.60

*The depth of penetration in 5 seconds.

made soybean curd softer than the control (calcium sulfate coagulated curd).

Moisture Content

The moisture content of soybean-cheese whey curds was between 82 and 89% (Table 3).

Water molecules are able to attach themselves to other molecules by means of a hydrogen bond (6) to form hydrates. The moisture contents of different proportions of soybean-cheese whey curds were slightly higher than soybean curd and cheese whey curd, which illustrates that a protein mixture of soybean and cheese whey possessed a higher water-holding capacity. The different sources of proteins may have different side chains, and when they are mixed, the interaction of protein molecules may alter their water-holding capacity.

Yield

There was a considerable difference among the various curds. The higher the ratio of cheese whey to soybean, the higher the yield of the curd (Table 4). A 100% cheese whey curd produced a much higher yield than a 100% soybean curd. The yield of the mixture was very close to the average of the yield of soybean curd and cheese whey curd. It was at least twice as much as the yield of the control. Yield is one of the advantages of making soybean-cheese whey curd.

Protein Content

The protein content of the mixture was lower than the plain soybean curd or cheese whey curd (Table 5) coagulated by the same coagulant, GDL. This was probably due to the interaction between soybean and cheese whey proteins which may hinder the precipitation. The protein solution may contain some salts which may offset the salting-out function. However, the protein content of the mixture curds was higher than that of the control.

Amino Acid Composition

The total sulfur-containing amino acid content of the mixture curds was higher than the soybean curd, especially the mixture curd made with the combined coagulants (Table 6). The half cystine content of the mixture curds made with GDL was absent, which lowered the total sulfur-containing amino acid content. This may be due to experimental error. However, the methionine content increased when cheese whey was added to the mixture. Cheese whey protein may be a good sulfur-containing amino acid supplement for soybean proteins.

In addition, all the mixture curds had higher threonine content than the soybean curd. Also, the combined coagulant showed higher lysine content than soybean curd. Compared with the control, the

TABLE 3.—Moisture Content of Soybean-Cheese Whey Curd (%).

Treatment	Percent Soybean / Percent Cheese Whey	100 / 0	60 / 40	55 / 45	50 / 50	45 / 55	40 / 60	0 / 100
$CaSO_4$		85.7						
G. D. L.		82.3	87.9	87.9	88.7	87.7	89.0	85.9
G. D. L. + $CaSO_4$		83.7	87.6	87.4	87.5	87.4	86.9	84.9
G. D. L. + $MgCl_2$		83.7	86.5	86.2	86.5	86.1	87.3	85.0

TABLE 4.—Yield of Soybean-Cheese Whey Curd (%, Dry Basis).

Treatment	Percent Soybean / Percent Cheese Whey	100 / 0	60 / 40	55 / 45	50 / 50	45 / 55	40 / 60	0 / 100
$CaSO_4$		25.8						
G. D. L.		34.6	55.2	58.1	61.9	63.6	63.3	86.9
G. D. L. + $CaSO_4$		33.6	52.6	56.2	59.1	60.4	61.9	83.3
G. D. L. + $MgCl_2$		35.7	56.2	57.7	59.9	63.1	65.9	89.5

TABLE 5.—Protein Content of Soybean-Cheese Whey Curd (%, Dry Basis).

Treatment	Percent Soybean / Percent Cheese Whey	100 / 0	60 / 40	55 / 45	50 / 50	45 / 55	40 / 60	0 / 100
$CaSO_4$		50.2						
G. D. L.		57.1	56.0	56.5	55.7	55.5	53.8	57.7
G. D. L. + $CaSO_4$		58.3	55.1	54.7	56.7	57.4	58.2	57.1
G. D. L. + $MgCl_2$		57.0	55.2	54.3	57.1	55.4	57.0	57.9

TABLE 6.—Amino Acid Composition of Soybean-Cheese Whey Curd (Micromole per 16 Milligrams of Sample).

	$CaSO_4$	G. D. L.			G. D. L. + $CaSO_4$			G. D. L. + $MgCl_2$		
Amino Acid	100% S*	100% S	100% W†	50% S 50% W	100% S	100% W	50% S 50% W	100% S	100% W	50% S 50% W
Lysine	3.3	4.2	4.6	1.8	3.2	5.7	4.8	3.5	4.7	5.4
Histidine	1.3	1.3		1.0		1.3	1.3			1.4
Ammonia	5.8	8.1	6.9	6.1	7.9	7.5	8.0	7.9	6.9	7.6
Arginine	2.9	2.0	1.0	1.4	1.5	1.2	1.7	2.2	0.7	1.7
Aspartic Acid	7.1	7.2	6.6	5.4	6.5		6.9	7.3	7.4	7.5
Threonine	2.9	3.0	3.0	3.4	2.4	3.8	3.3	2.7	3.8	3.0
Serine	3.6	3.2	2.5	2.8	2.9	2.4	3.2	3.5	3.1	3.3
Glutamic Acid	8.0	8.7	7.3	6.9	7.8	8.1	7.8	8.5	8.0	8.2
Proline	4.3	4.7	3.4	2.9	3.6	4.1	3.6	4.3	3.8	3.6
Glycine	4.3	4.0	2.6	2.4	4.0	2.1	3.0	4.1	2.7	3.0
Alanine	4.2	4.4	4.8	4.0	4.3	5.0	5.3	3.7	5.5	4.5
Valine	4.3	4.1	3.7	3.6	3.8	4.5	4.0	3.7	4.1	3.6
Half Cystine	0.7	1.0	0.8			1.7	1.5	0.4	1.9	1.3
Methionine	0.4	0.7	0.9	1.1	0.6	1.6	1.0	0.6	1.1	0.7
Isoleucine	3.7	3.9	3.5	3.7	3.4	4.2	3.7	3.3	4.1	3.7
Leucine	4.9	6.2	5.4	5.9	4.8	6.9	6.6	5.4	7.0	6.0
Tyrosine	1.3	1.5	1.4	1.6	1.4	1.8	1.7	1.5	1.5	1.5
Phenylalanine	1.9	2.7	2.0	1.8	2.6	2.1	2.2	2.4	1.8	1.9

*Soybean.
†Cheese whey.

other essential amino acid content of the curd also increased.

CONCLUSIONS

Soybean-cheese whey curd was made by coagulation of soybean and cheese whey protein mixture with glucono-delta-lactone or a combination with other salts. It was a white, soft, gelatinous mass which had an acceptable aroma and texture, higher yield, proper moisture and protein content, and promising amino acid composition. The addition of cheese whey protein to soybean protein enriched the essential amino acid content of soybean protein to upgrade its quality.

The Ohio process for preparation of a soybean-cheese whey food product is simple, and its product is nutritious. It may provide an inexpensive protein source or a potential new product such as non-dairy yogurt, cream pie filling, pudding, or other analogs. A U. S. Patent, No. 4,105,803 dated August 8, 1978, has been issued to the Ohio Agricultural Research and Development Center, Wooster, Ohio, covering this work.

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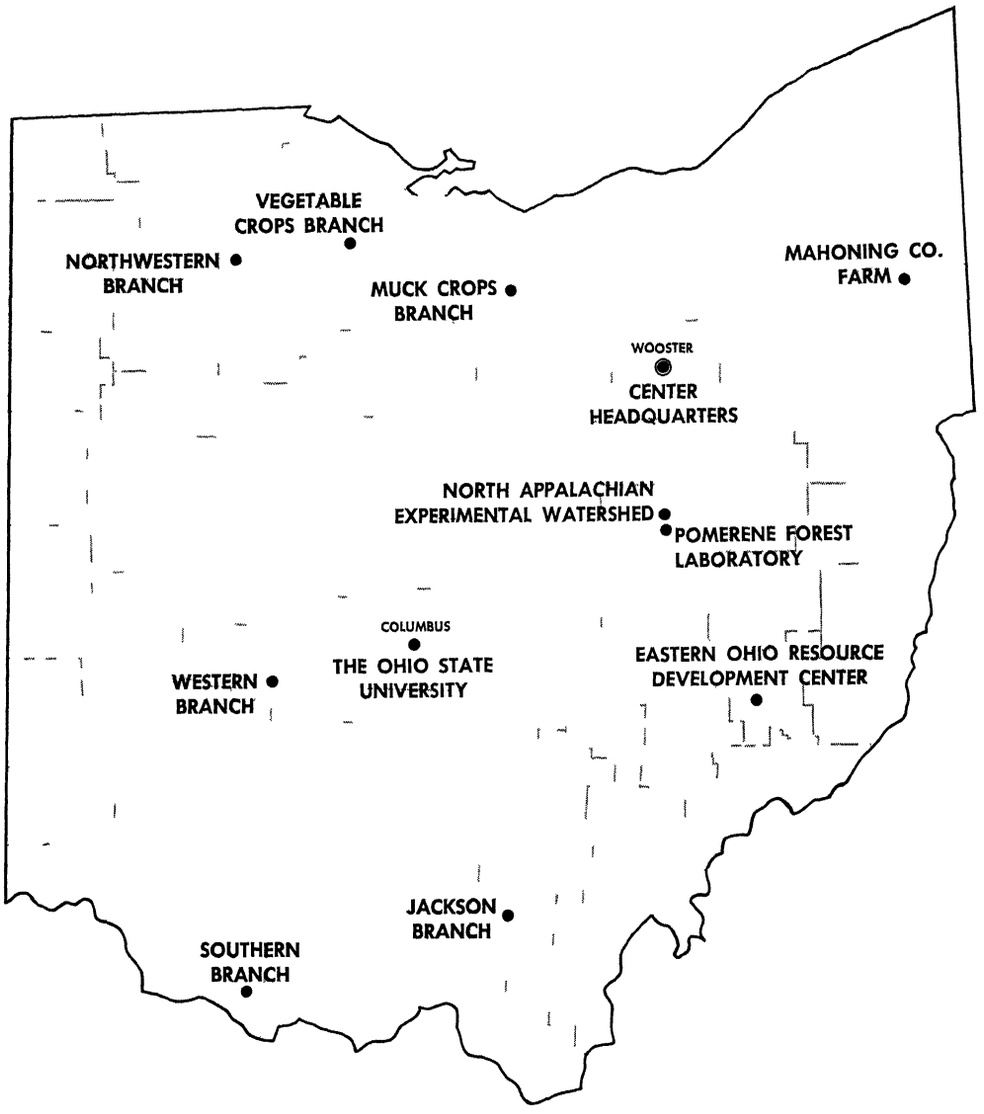

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Research is conducted by 15 departments on more than 7000 acres at Center headquarters in Wooster, eight branches, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University

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Mahoning County Farm, Canfield 275 acres

Muck Crops Branch, Willard, Huron County 15 acres

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Pomerene Forest Laboratory, Coshocton County 227 acres

Southern Branch, Ripley, Brown County 275 acres

Vegetable Crops Branch, Fremont, Sandusky County 105 acres

Western Branch, South Charleston, Clark County 428 acres